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RESEARCH

Investigation of springback behavior in creep age forming of AA2024 sheets used in the aerospace industry

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Abstract
Although inverse relationships among sheet thickness, forming pressure, and springback are widely reported in the creep-age forming (CAF) literature, limited statistically validated experimental data exist for AA2024 undergoing a T3-T81 transformation under industrial autoclave conditions. This study experimentally investigates and parametrically assesses the springback behavior of AA2024-T3 sheets, focusing on the comparative sensitivity of thickness (0.81–1.6 mm) and pressure (6–9 bar). Two-factor ANOVA confirmed statistically significant main effects for both parameters ($p<0.001$), while a multiple linear regression model ($R^2=98.27\%$) was developed to quantify their influence. The independence of these predictors was verified using the Variance Inflation Factor (VIF) analysis (VIF = 1.00). The results show that springback decreases from 68.4% to 53.0% over the investigated window, a trend fundamentally driven by stress-relaxation kinetics and the precipitation of fine S′ phases that stabilize the microstructure. Furthermore, thickness thinning remained negligible (<1%), and the achievement of the T81 state was confirmed by hardness and electrical conductivity measurements. While the model provides a robust tool for preliminary mold compensation, its applicability is limited to the evaluated industrial parameter space and cylindrical geometry. These findings provide statistically supported guidance for optimizing CAF processes in aerospace structural applications.

Keywords Creep age forming · AA2024 · Stress relaxation · Aging heat treatment · Springback

Introduction

The aerospace industry requires advanced manufacturing techniques to produce high-performance components that meet close dimensional tolerances, possess superior material properties, and feature complex geometries. Among the various manufacturing processes used for such components, Creep Aging Forming (CAF) has attracted significant attention for its ability to simultaneously shape and heat-treat materials, thereby optimizing mechanical properties. The CAF process combines two critical operations: forming, which shapes the material into the desired configuration, and aging, which enhances the material's strength via heat treatment. The CAF process involves forming the plate against a tool, then artificial aging under load, followed by unloading. Since stress relaxation can only release a portion of the stresses within the loaded plane, considerable springback typically occurs after unloading [1–4]. The manufacturing stages of the CAF process are illustrated in Fig. 1.

One of the primary challenges in the CAF process is springback, a phenomenon where the material partially returns to its original shape after forming due to elastic recovery. Springback can lead to dimensional inaccuracies, complicating the achievement of the tight tolerances required in aerospace manufacturing. This phenomenon is influenced by various factors, including the material's mechanical properties, the forming conditions, and the process parameters [4–6]. Figure 2 shows the progression of stress and strain throughout the loading, stress-relaxation,

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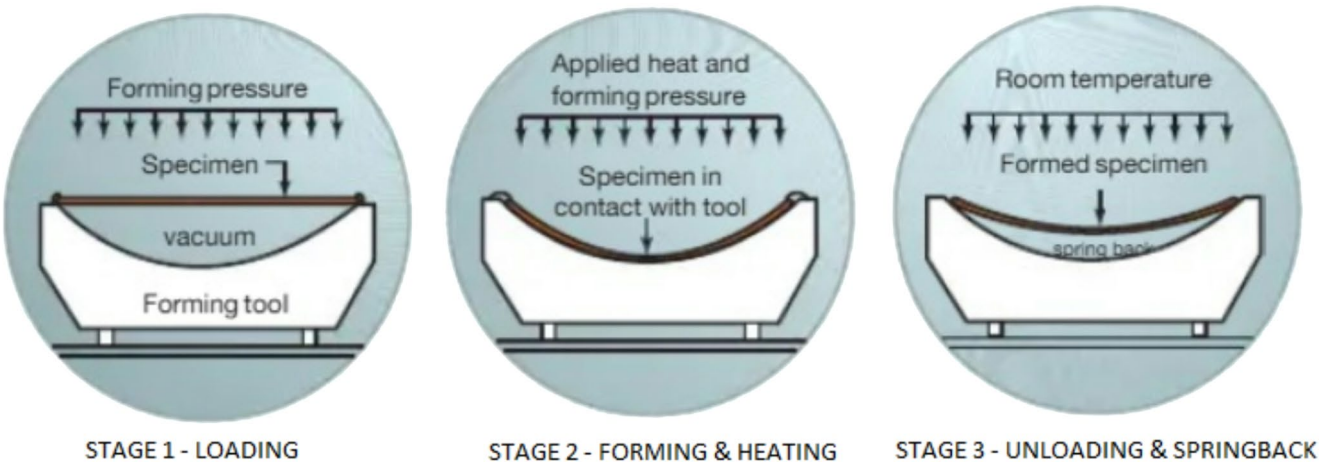


Fig. 1 Manufacturing stages of creep age forming [10]

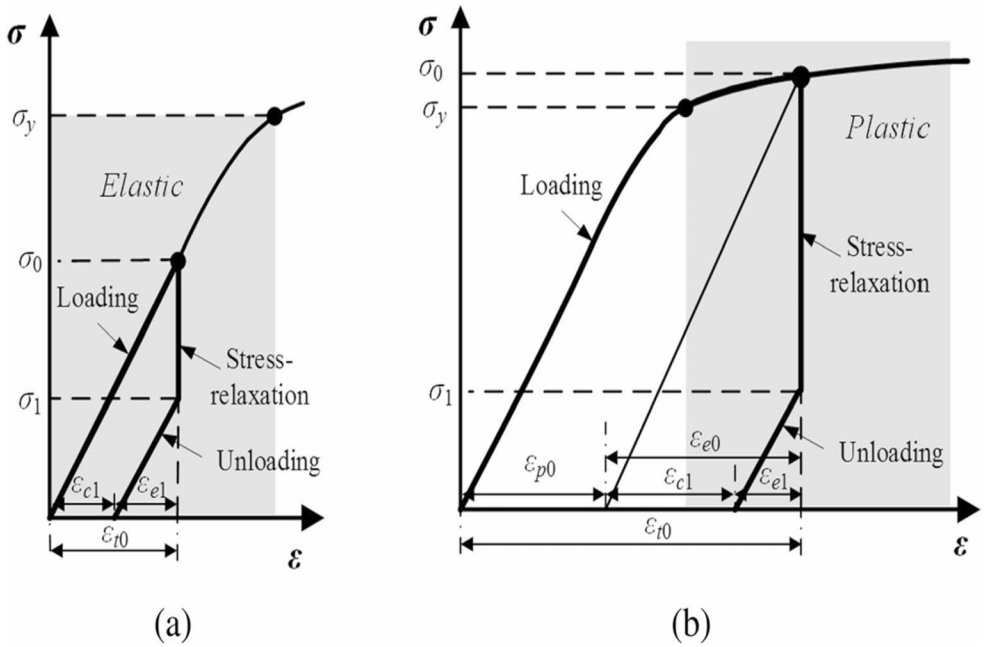


Fig. 2 Illustrating the springback mechanism in (**a**) the elastic region and (**b**) the plastic region [7]

and unloading stages of CAF under both elastic and plastic loading conditions. For the elastic loading case (Fig. 2a), the initial stress σ0 reduces to σ1 after stress relaxation, and σ1 is then released during unloading, which produces the elastic strain recovery (εe1) responsible for springback. In the case of plastic loading (Fig. 2b), springback occurs through the same mechanism, except that an initial plastic strain (εp0) is introduced during the loading stage [7–9].

Autoclave pressure and material thickness are particularly significant among the process parameters influencing springback in CAF. The autoclave, a sealed vessel used to apply heat and pressure during the forming and aging stages, is crucial in ensuring uniform material properties and minimizing deformation errors. The pressure applied within the autoclave affects the rate of plastic deformation during forming and influences the extent to which the material returns to its original shape post-forming. As autoclave pressure increases, the material experiences more uniform compressive forces, which can mitigate springback by promoting more controlled deformation [1–3, 10]. Additionally, material thickness plays a key role in determining springback behavior. Thicker materials exhibit better resistance to elastic recovery due to their increased stiffness. This resistance to deformation and recovery increases with thickness, implying that thicker sheets may exhibit lower springback than thinner sheets under identical forming conditions [6, 11]. This relationship is particularly significant when working with 2024 aluminum alloy, a widely used aerospace material renowned for its excellent strength-to-weight ratio and fatigue resistance [3, 12, 13]. Typically, the alloy is used in the T3 temper, which provides good

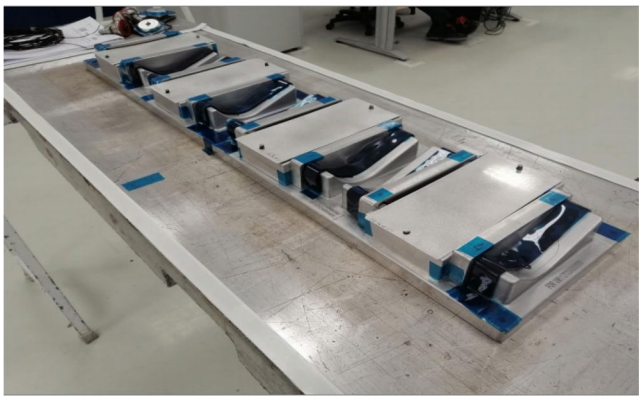


Fig. 3 Preparation of the experimental setup for autoclave processing: (**a**) cylindrical forming die ($R = 1500$ mm), (**b**) AA2024-T3 test specimen, and (**c**) initial positioning of the sheet prior to vacuum bagging



Fig. 4 Detailed view of the vacuum bagging assembly components: (**a**) sealant tape for airtight sealing, (**b**) breather layer for uniform air evacuation, (**c**) vacuum film (bagging), and (**d**) high-temperature vacuum port connections for pressure maintenance during the 12-hour cycle

formability and strength [14]. However, the alloy is often heat-treated to achieve the higher-strength T81 temper for applications requiring enhanced mechanical properties [15–18]. Although thickness-dependent springback behavior is commonly observed across metallic alloys, its quantification during the CAF-based T3-T81 transformation of AA2024 remains industrially relevant due to the coupled creep–aging response of 2xxx series alloys. Despite the critical importance of understanding springback in aerospace manufacturing, limited research has examined the simultaneous effects of autoclave pressure and material thickness on springback behavior, particularly in the context of 2024 aluminum alloy during the creep-aging forming process.

This study aims to address this gap by experimentally investigating the effects of autoclave pressure and material thickness on the springback behavior of 2024 aluminum alloy during creep-aging forming. The primary objective is to identify the relationships between these key parameters and springback, and to provide insights into optimizing process conditions to improve dimensional accuracy. The findings of this study are expected to contribute significantly to the mold design phase of CAF, where understanding springback is essential for producing parts that meet the strict dimensional tolerances required in aerospace manufacturing. The research aims to broaden the understanding of creep-age forming as an effective method for producing high-performance materials with complex geometries. It provides aerospace manufacturers with the necessary tools to enhance the efficiency and precision of the CAF process. Although inverse relationships among thickness, forming pressure, and springback are generally reported in the CAF literature, few studies provide statistically validated experimental data for AA2024 under industrial autoclave conditions during the T3-T81 transformation. The present study aims to bridge this gap by providing experimentally validated parametric relationships and an empirical regression model applicable to mold design optimization.

Material and method

The CAF process begins with preparing a sheet metal workpiece in its unformed state. The workpiece is initially cut to the final dimensions using advanced machining techniques, such as CNC routing, punching, or other cutting methods, to meet the required tolerance specifications. The workpiece's (tool & workpiece's) surfaces are meticulously prepared to improve adhesion quality, particularly in areas designated for sealing tape application. This preparation involves sanding to achieve a uniform surface profile, followed by cleaning with appropriate chemical agents to remove contaminants, such as oils or residues, that may interfere with adhesion. Once the surfaces are prepared, the components are accurately positioned onto the mold. The mold geometry consisted of a single-curvature cylindrical surface with a fixed radius of curvature ($R = 1500$ mm). The curvature radius remained constant throughout all experiments to isolate thickness and pressure effects (Fig. 3.).

During vacuum bagging, thermocouples are strategically placed to monitor temperature profiles, and vacuum ports are installed to prevent negative pressure from forming in the forming direction. A vacuum bag (Fig. 4) is applied over the assembly, and air is extracted using vacuum pumps to create a sealed environment.

The vacuum levels are continuously monitored with high-precision vacuum gauges to prevent air leakage, a critical factor in maintaining process integrity. After verifying the absence of air leakage, the sealed assembly is transferred into an autoclave for processing. The heating rate of the autoclave can reach up to 5 °C/min (as required by AMS 2770 for heat treatment from T3 to T81), and the tolerance



Fig. 5 Post-forming springback measurement process: (**a**) 3D coordinate measuring machine (CMM) probe, (**b**) formed AA2024-T81 part, and (**c**) reference points used for calculating the final radius of curvature and springback ratio

after the temperature is fixed is ± 1 °C [19]. The workpiece is subjected to a controlled combination of elevated temperature and pressure in the autoclave to achieve the desired material and geometrical properties. Upon completion of the autoclave cycle, the assembly is carefully removed, the vacuum bag is dismantled, and the processed specimens are extracted from the molds, ensuring no damage occurs (Fig. 5). The resulting parts are subjected to quality assurance inspections to confirm compliance with the specified design and material criteria.

The 2024 aluminum alloy was selected owing to its widespread use in aerospace applications. The chemical composition is given in Table 1. Four sheet thicknesses were considered: 0.81 mm, 1.016 mm, 1.27 mm, and 1.6 mm, corresponding to the material specifications commonly used in the aerospace sector. The aging parameters—specifically, temperature and aging time—were determined by transforming T3-tempered aluminum alloy to T81 temper, per AMS 2770 [19]. These parameters were maintained constant across all experiments. The materials were subjected to the CAF process at 190 °C for 12 h, in accordance with the recommended procedure for achieving the desired temperature. The artificial aging process was conducted in accordance with AMS2770 for the T3-T81 transformation of AA2024 alloys. This rigorous compliance with aerospace standards ensures the reproducibility of the thermal cycle and effectively isolates the mechanical influence of sheet thickness and autoclave pressure on the resulting springback behavior, as highlighted by the experimental design.

The autoclave pressure was varied across four levels: 6 bar, 7 bar, 8 bar, and 9 bar, while material thickness was the primary variable under investigation. External process parameters, including mold geometry and process time, were held constant to isolate the effects of autoclave pressure and material thickness on springback behavior. The pressure range of 6–9 bar was chosen to reflect standard industrial autoclave operating conditions in aerospace CAF applications. Pressures below this range may result in insufficient tool–sheet conformity, whereas significantly higher pressures are generally avoided due to equipment limitations and potential material overstressing. Accordingly, the selected pressure interval provides a realistic and industrially relevant framework for assessing springback behavior. Hardness and conductivity measurements were performed in accordance with ASTM E10 and ASTM E1004 standards, respectively [20, 21]. The hardness and conductivity values for the aluminum alloy aged to the 2024-T81 temper were referenced from AMS 2658 [22]. Hardness measurements were obtained using the Mitutoyo 810-203D hardness testing device. Conductivity measurements were performed using the Verimet M4900C conductivity meter. Springback rates were measured and analyzed to assess the influence of these two key variables (autoclave pressure and material thickness). Springback measurements were conducted using a Coordinate Measuring Machine (CMM). The CMM measurement uncertainty was ± 0.01 mm according to the manufacturer's specification. Considering the maximum deflection values measured, the relative uncertainty remained below 0.5%, which is significantly lower than the observed springback variations. To ensure reproducibility and clarity, springback was quantified using the maximum deflection method based on CMM measurements. Let.

- δ_m= maximum deflection of the mold geometry (reference deflection),
- δ_p= maximum deflection of the formed part after unloading.

The springback ratio (SB) was calculated as:

$$SB\,(\%) = \frac{\delta_m - \delta_p}{\delta_m} \times 100$$

where a higher SB value indicates greater elastic recovery after unloading.

All deflection measurements were taken at the geometrical centerline of the specimen using the deepest point of the

Table 1 Chemical composition of AA2024 (%)

Cu	Mg	Mn	Si	Fe	Cr	Zn	Ti	Other	Al
3.8–4.9	1.2–1.8	0.3–0.9	≤0.50	≤0.50	≤0.10	≤0.25	≤0.15	≤0.15	Balance

mold as the reference coordinate. The maximum deflection method was employed, with the deepest point on the mold utilized as a reference. Springback rates were subsequently calculated based on these measurements. Statistical analysis was conducted using a two-factor ANOVA (additive model) to evaluate the main effects of thickness and pressure. Due to the absence of replicated independent specimens within each condition, interaction effects could not be statistically estimated.

Results and discussion

Springback values represent averaged measurements obtained under each experimental condition. Due to the absence of independently replicated specimens per condition, standard deviation values are not reported. However, measurement uncertainty analysis confirmed that the relative error remained below 2% for all cases. The uncertainty of the CMM system was ± 0.01 mm, according to the manufacturer's specifications. The results demonstrate that autoclave pressure and material thickness significantly affect springback in the final-formed parts. Hardness and electrical conductivity measurements were performed to verify the attainment of the 2024-T81 temper condition after CAF processing. Hardness values were within the specified range for the T81 temper. This stabilization at the T81 state is fundamentally linked to the kinetics of stress relaxation and creep strain accumulation during the 12-hour aging cycle. In AA2024 alloys, the application of autoclave pressure at 190 °C initiates dislocation climbs and glide mechanisms, effectively converting elastic energy into permanent viscoplastic strain. This process is further stabilized by the T3 - T81 transformation, in which the precipitation of fine S′ (Al_2CuMg) phases pins the moved dislocations, hindering the material's tendency to recover elastically upon unloading [14, 17]. Beyond dimensional accuracy, this microstructural transition also ensures the structural integrity of the formed components. Localized thinning was monitored and found to be negligible (below 1%) across all specimens, primarily due to the large die radius (R = 1500 mm), which maintains low forming strains. While direct residual stress mapping was outside the current scope, the uniformity of these aging indicators suggests a controlled, stable stress-relief process. Consequently, the synergy between externally applied pressure and internal precipitate evolution not only mitigates springback but also ensures that the final parts meet the high-strength requirements essential for aerospace applications. Electrical conductivity was measured using the eddy-current method in accordance with ASTM E1004, and the resulting values (35–45% IACS) met the requirements of AMS 2658 [21, 22]. These results confirm that the artificial aging stage of the CAF process successfully achieved the intended temper condition.

Springback measurements were performed using CMM and the maximum deflection method. The springback rates were determined by taking the deepest point on the mold as a reference. Graphs depicting the relationships between material thickness and springback rates, as well as process pressure and springback rates, are shown in Figs. 6 and 7, respectively.

For all applied forming pressures (6–9 bar), springback consistently decreased with increasing material thickness. At 6 bar, springback decreased from 68.4% at 0.81 mm to 61.5% at 1.6 mm; similarly, at 9 bar, it decreased from 61.7% to 53.0% over the same thickness range. This corresponds to an overall reduction of approximately 7–9% points, depending on the pressure level. To quantify the individual and combined influences of sheet thickness (t) and autoclave pressure (P) on the springback ratio (SB), a multiple linear regression analysis was performed. Based on the experimental data, the empirical relationship is

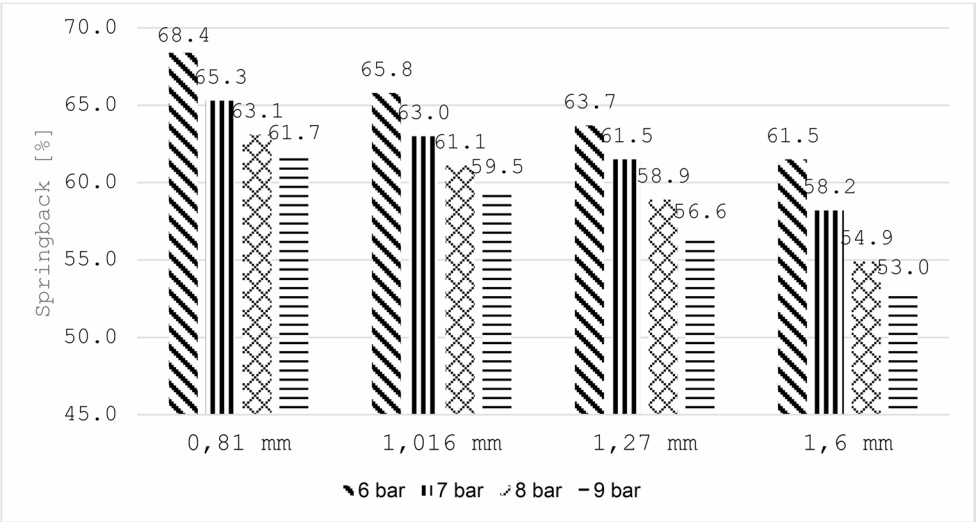


Fig. 6 Influence of sheet thickness on the springback ratio of AA2024-T81 sheets. The data points represent averaged measurements across the investigated pressure window (6–9 bar) at a constant forming temperature of 190 °C

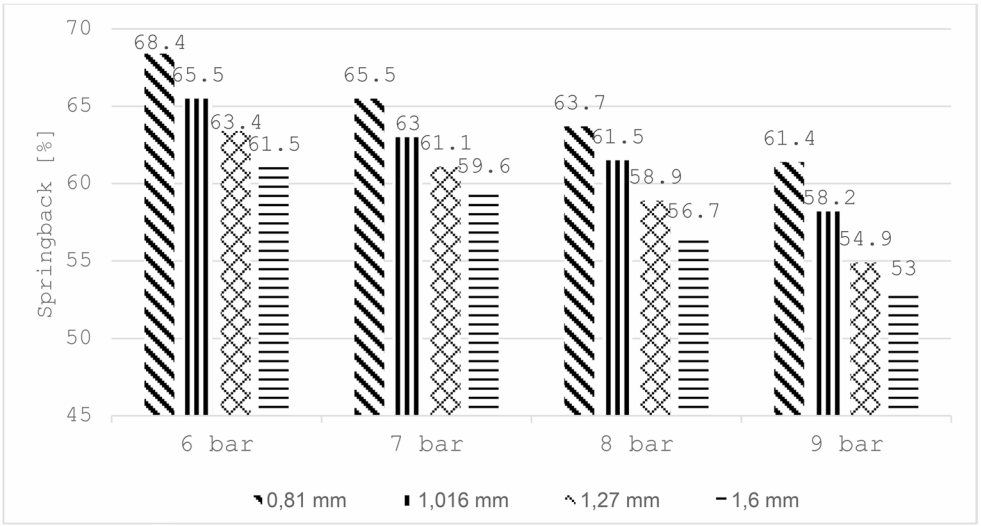


Fig. 7 Relationship between autoclave pressure and springback ratio for various sheet thicknesses (0.81–1.6 mm). A consistent reduction in springback is observed as pressure increases, indicating enhanced stress redistribution during the 12-hour creep aging cycle

Table 2 Analysis of variance (ANOVA) for the springback regression model

Source	DF	Adj SS	Adj MS	F-Value	*P*-Value
Regression	2	237,359	118,680	369,23	0,001
Thickness	1	130,637	130,637	406,43	0,001
Pressure	1	106,722	106,722	332,03	0,001
Error	13	4,178	0,321		
Total	15	241,537			

established as follows: SB = 89.68 − 9.685t − 2.310P. The statistical significance of this model was evaluated using Analysis of Variance (ANOVA), as summarized in Table 2. The results demonstrate a high degree of fit, with a coefficient of determination (R^2) of 98.27% and an adjusted R^2 of 98.00%, indicating that approximately 98% of the variance in springback is explained by the selected parameters. The standard errors for the thickness and pressure coefficients were 0.480 and 0.127, respectively, and the overall model was significant ($F = 369.23$, $p < 0.001$). Furthermore, Variance Inflation Factors (VIF) for both predictors were calculated as 1.00, confirming the absence of multicollinearity and verifying that thickness and pressure act as independent drivers of springback behavior. It should be noted, however, that this independence is characterized within a fixed cylindrical die geometry ($R = 1500$ mm). While the model provides high predictive reliability for the studied industrial window, factors such as localized friction and varying curvature radii—which were kept constant to isolate parametric sensitivities—remain critical variables for future multi-axial forming studies.

Both coefficients are negative, confirming the monotonic reduction of springback with increasing thickness and pressure. For example, at 0.81 mm thickness, springback decreased from 68.4% at 6 bar to 61.7% at 9 bar, while at 1.6 mm thickness it decreased from 61.5% to 53.0%. However, the reduction associated with thickness variation was generally more pronounced than that associated with pressure variation, indicating that thickness selection plays a more critical role than pressure adjustment in minimizing springback within the investigated CAF conditions. The consistent trend observed across all pressure levels indicates that thickness optimization may represent a more effective strategy than solely increasing autoclave pressure for controlling springback in aerospace CAF applications. The reduction in springback with increasing material thickness can be explained by the plastic deformation characteristics of aluminum alloys [4, 5]. These findings underscore the importance of material thickness as a key factor in determining the dimensional accuracy of formed parts, particularly in processes such as CAF that involve both plastic deformation and aging. Thinner sheets, being less stiff, experience higher strain rates during forming, making them more prone to elastic recovery and, consequently, greater springback [4, 5, 11]. In contrast, thicker sheets, with higher moments of inertia and greater resistance to bending, exhibit less elastic recovery after forming, thereby significantly mitigating springback. The reduction in springback is more pronounced in thicker materials due to their greater rigidity and stability [4]. Such outcomes have important implications for the CAF process, particularly in aerospace applications, where the thickness of components such as wing panels and fuselage structures is carefully optimized to achieve the desired strength-to-weight ratio [11]. The greater influence of thickness can be explained by bending-stiffness scaling ($D \propto t^3$), which significantly increases resistance to elastic recovery. In contrast, pressure primarily enhances stress redistribution and creep strain accumulation during aging. During CAF and the T3 - T81 transformation, stress relaxation and creep strain accumulation reduces residual elastic strain energy. Increased pressure promotes stress redistribution and viscoplastic deformation, thereby lowering springback.

Consequently, springback reduction results from both diminished stored elastic energy and enhanced time-dependent creep strain accumulation. A comprehensive understanding of the correlation between material thickness and springback is essential for the structural design of aerospace components. Increased thickness generally reduces elastic recovery, enabling higher dimensional accuracy with minimal die compensation.

Another significant observation from the experimental results is the reduction in springback with increasing autoclave pressure. Specifically, as the forming pressure increased from 6 bar to 9 bar, the springback rate decreased markedly. This suggests that higher autoclave pressures are crucial in minimizing elastic recovery in the material after forming. The reduction in springback with increased autoclave pressure can be attributed to several mechanisms. Elevated forming pressure promotes a more uniform stress distribution throughout the material, thereby enabling homogeneous plastic flow and reducing strain localization. This condition mitigates the material's propensity to undergo elastic recovery and return to its initial configuration after unloading. Furthermore, increased autoclave pressure effectively suppresses localized instabilities and non-uniform deformation modes, which are primary contributors to variable springback behavior. Higher pressure enables more controlled deformation, minimizing elastic recovery and enhancing dimensional accuracy in the final part. This reduction in springback with increased autoclave pressure is interpreted as a consequence of enhanced time-dependent creep strain accumulation during the 12-hour aging cycle. Higher forming pressure is thought to promote stress redistribution and viscoplastic deformation, thereby lowering the stored elastic energy that would otherwise be released upon unloading. This relationship between autoclave pressure and springback is supported by various studies in the literature. While previous studies by Holman [2] and Lam et al. [22] reported that higher forming pressures reduce deformation variability in aluminum alloys by improving strain distribution, our experimental data specifically quantify this effect for the T3-T81 transformation of AA2024 sheets within a 6–9 bar window. Furthermore, whereas prior research often focuses on final geometry, the findings provide a statistically validated regression model that links these industrial pressure levels directly to springback ratio mitigation.

Although interaction effects could not be statistically estimated due to the absence of replicated specimens within each condition, the consistently monotonic reduction trends observed across all parameter combinations suggest a combined beneficial influence of thickness and pressure on springback reduction. Within the investigated range, thickness had a stronger effect than pressure. Specifically, the reduction in springback was more pronounced when both thicker materials and higher autoclave pressures were used. This finding suggests that when optimized together, these two factors can significantly reduce springback —a critical consideration in the manufacturing of aerospace components. The combined influence of thickness and pressure is consistent with the established theory of stress relaxation in 2xxx series alloys, where the precipitation of strengthening phases during the T3 to T81 transformation likely stabilizes the deformed state. While not directly observed via microstructural imaging in this study, this interpretation aligns with the measured hardness and conductivity trends, suggesting that the reduction in springback results from the additive contribution of increased bending stiffness and time-dependent strain accumulation. The interaction between material thickness and autoclave pressure can be explained in terms of material flow and deformation mechanics. Thicker materials are inherently less prone to elastic recovery due to increased rigidity and resistance to bending. However, when higher forming pressures are applied, the material undergoes more controlled plastic deformation, further minimizing springback. This combined effect of increased material thickness and pressure results in a more homogeneous strain distribution, reducing local deformations and enhancing overall dimensional stability. This interaction is particularly beneficial for aerospace applications, where parts are subjected to high mechanical loads and must maintain precise dimensional integrity over their operational lifespan. While interaction effects could not be statistically estimated due to the absence of replicated specimens, the consistently monotonic reduction trends observed across all parameter combinations suggest a combined beneficial influence of thickness and pressure on springback reduction. Within the investigated range, thickness and pressure operate as independent simultaneous drivers. This is further supported by the VIF of 1.00 for both predictors, confirming that the reduction in springback results from the additive contribution of increased bending stiffness and enhanced stress redistribution. For example, Zhan et al. demonstrated that combining increased material thickness and forming pressure can significantly improve the accuracy of formed parts by reducing elastic recovery [4]. Similarly, Jeunechamps et al. found that higher autoclave pressures promote better material flow and suppress localized deformations, resulting in more accurate, dimensionally stable components [6]. Simultaneously optimizing material thickness and forming pressure is an effective strategy for mitigating springback and achieving the dimensional fidelity required in aerospace structures.

Springback remains a critical challenge in aerospace component manufacturing, directly influencing the dimensional accuracy and functional performance of the final parts. Effective springback control is crucial for meeting

the stringent dimensional tolerances required in aerospace applications. By understanding how autoclave pressure and material thickness influence springback, manufacturers can make informed decisions regarding mold geometry, process parameters, and material selection. Jeunechamps et al. emphasized that mold designs can be optimized for springback by adjusting for expected elastic recovery based on material thickness and forming pressure [6]. This ensures the final shape of components remains within required tolerances, improving overall process efficiency and part accuracy in aerospace applications. These predictive models can be employed early in the design phase to simulate material behavior during forming, thereby reducing the need for trial-and-error approaches. Zhan et al. highlighted that this predictive capability can significantly enhance manufacturing process efficiency, improve control over final part geometry, and reduce production costs [4]. The CAF process can fabricate high-performance parts with intricate geometries and minimal post-processing by optimizing parameters like autoclave pressure and material thickness. The identified parameter sensitivities provide practical guidance for mold compensation and early-stage process design in CAF applications.

Conclusions

This study presents an experimentally validated parametric assessment of springback behavior in AA2024 sheets undergoing a T3-T81 transformation during CAF under industrial autoclave conditions. Based on the results obtained within the investigated industrial window, the following conclusions are drawn:

- Within a thickness range of 0.81–1.6 mm and a pressure window of 6–9 bar, the springback ratio decreased from 68.4% to 53.0%.
- Multiple linear regression analysis ($SB = 89.68 - 9.685t - 2.310P$) and two-factor ANOVA confirmed that both sheet thickness and autoclave pressure exert statistically significant main effects ($p < 0.001$) on springback.
- The dominant role of thickness is consistent with bending stiffness scaling ($D \propto t^3$), which substantially increases resistance to elastic recovery, whereas pressure primarily contributes through enhanced stress redistribution and interpreted creep strain accumulation during aging.
- The high coefficient of determination ($R^2 = 98.27\%$) indicates strong internal consistency within the 16-point experimental design, providing a reliable foundation for preliminary mold-compensation strategies in aerospace applications.
- The practical applicability of the proposed model is strictly bounded by the investigated parameter range (0.81–1.6 mm and 6–9 bar) and the specific cylindrical mold geometry ($R = 1500$ mm). Predictive accuracy for complex double-curvature geometries remains a subject for future investigation.

While the absence of independent replicates is acknowledged as a limitation of the present study, the consistent monotonic trends observed across all parameter combinations support the robustness of the identified main effects. Future studies incorporating replicated experimental designs and microstructural characterization, such as TEM or SEM analysis, may further refine the mechanistic understanding of creep–relaxation–aging interactions in AA2024 alloys.

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Author contributions All authors contributed to the conception and design of the study. Başaran Bekir Başpınar and İbrahim Uslan performed material preparation, data collection and analysis. Mehmet Fatih Aycan wrote the first draft of the manuscript, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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