Finite element-assisted fatigue life evaluation of notched Aisi 316l: comparative insights into v-notch and rectangular notch geometries

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Abstract. The present work illustrates a comprehensive fatigue life assessment methodology for notched AISI 316L stainless-steel specimens employing a hybrid experimental-FEM framework. V-shaped and rectangular notches were introduced into fatigue specimens designed as per ASTM E606 standard to represent real-world geometric discontinuities. Tensile strength was evaluated from experimentation and used as input to in ANSYS Workbench 18.1 to simulate fatigue behaviour under cyclic axial loading. A Taguchi L9 orthogonal design was used to vary notch width, depth, and central angle to quantify their effect on the fatigue response. Results showed a drastic reduction in fatigue life due to notches in all cases. V-notches yielded higher stress concentrations and lower fatigue lives than rectangular notches in most of the cases. The un-notched specimen under the same loading experienced a maximum stress of 228.91 MPa and infinite fatigue life whereas the notched specimens experienced an extreme decrease in fatigue life with values between 68 to 17720 cycles. The rectangular notches promoted broader plastic zone development and favourable stress redistribution, whereas V-notches localized strain energy, expediting crack initiation. Central angle and depth were found to be the most critical parameters for V- and rectangular notches respectively. Quantified insights about fatigue life degradation due to notch profiles is attained by this work and it is critical for biomedical, marine, and structural applications.

1 Introduction

In engineering applications like marine, biomedical, and energy sectors, components are exposed to repeated cycles of loading rather than only static forces. In this kind of loading, fatigue damage is an important consideration, which is accumulated slowly in a small area, beginning at stress raisers like notches, holes, irregular geometry, etc., which could, in turn, lead to failure by sudden fracture. Although features like this are critical for assembly, function, and weight saving. Thus, it is necessary to understand accurately the fatigue response of a component containing a notch in order to ensure that the designed structure is safe for a specified period of time during which it is in service.

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AISI 316L austenitic stainless steel is widely employed in structures exposed to harsh service conditions because it offers a combination of excellent corrosion resistance, high ductility, and a stable austenitic microstructure. Typical applications range from marine components and orthopaedic implants to equipment in chemical processing plants. Despite these advantages, it is still vulnerable to fatigue damage, particularly when complex, multiaxial stress states develop around geometric discontinuities such as V-notches and rectangular notches. The influence of these notches on local stress and strain fields is highly non-trivial, and traditional stress-life approaches often struggle to deliver accurate fatigue life predictions in such situations.

The geometrical characteristics of notches strongly governs how stress and strain are distributed and concentrated near the notch tip [1]. Classical approaches such as Neuber's rule, Peterson's notch sensitivity factor, and the theory of critical distances (TCD) have long been used to link these geometric parameters to fatigue life. However, many of these models rely on simplifying assumptions, for example strictly linear-elastic behaviour or nearly uniform stress fields, which can limit their accuracy in real components. A few studies have also indicated that notches, residual stresses, and inherent material microstructure characteristics influence fatigue response in a critical manner [2]. For example, based on stress life relationships, fracture mechanics concepts, and finite element (FE) analysis, a model for estimating high-cycle fatigue (HCF) life in notched specimens under compressive residual stresses was established by Xiao, et al. Their model predicted, for specimens made of AISI 316L stainless steel, much more accurate fatigue lives than those predicted by S-N curve approaches [3].

Zhang et al. introduced a method based on data to forecast how cracks grow in damaged parts, applying machine learning techniques. Instead of direct training, they used a neural network that adjusts through error feedback to capture links between crack speed and the effective stress intensity factor. Because real world measurements were scarce, a selection process guided by multiple models called Query-by-Committee helped pick informative samples, boosting precision without needing large datasets. This led to lower needs for lab work and computing power. Furthermore, it gave more accurate results compared to standard regression approaches [4]. The role of geometric and statistical size effects on fatigue response in notched parts has received broad attention. While studying different alloys, Ye et al. expanded the traditional TCD method by including a relative stress gradient (RSG) factor, this helps capture changes in fatigue due to notch dimensions. Their updated version was validated through experiments, showing improved accuracy across diverse notch shapes. Adjusting the critical distance via RSG makes the method respond better to material differences, particularly under medium or low cycle conditions [5]. Since multiaxial stresses and intricate local responses complicate analysis near notches. Ma et al. proposed a revised critical plane approach combining notch support terms with a time varying damage weighting strategy. In this method, the complex stress state around the notch was directly considered, while the choice of critical plane shifted according to damage from prior loading at that location. Applied to TC4 and GH4169 alloys, the model delivered improved fatigue life estimates compared to traditional single-axis approaches [6].

As engineering designs grow more complex and additive manufacturing becomes commonplace, there is an increasing demand for fatigue life prediction methods that can cope with real service conditions, nonlinear material response, multiaxial loading, and cyclic plasticity concentrated at notch roots. Against this backdrop, FE-based fatigue analysis has emerged as a central tool in computational mechanics. It enables high-fidelity representation of stress concentration zones and, importantly, makes it possible to impose realistic boundary conditions while also accounting for material nonlinearities [7]. By integrating FEM results with strain-life-based fatigue damage models like the Smith-Watson-Topper (SWT) criterion, researchers can achieve more accurate fatigue life predictions under complex loading states.

Despite significant progress in fatigue modelling, the influence of notch geometry on the fatigue life of AISI 316L remains insufficiently explored. Although many studies analysed notched components, direct comparisons of V- and rectangular-notched specimens using high-fidelity FEM are rare. Earlier works typically treat single geometries or adopt simplified assumptions, without a unified computational framework that captures the sensitivity to notch shape and dimension. This investigation addresses that gap through a comprehensive FEM-based fatigue analysis of AISI 316L specimens containing both V-shaped and rectangular notches with systematically varied geometric parameters. By maintaining identical loading and material conditions, the study isolates the role of notch shape on stress localisation and fatigue life. The proposed framework, implemented via ANSYS's fatigue tool, enhances predictive fidelity and delivers design-relevant insights for fatigue-critical components in marine, biomedical and structural engineering applications. The objectives of the present work are:

- To quantify the influence of notch geometry on fatigue performance of AISI 316L stainless-steel by performing a controlled, side-by-side finite-element (FE)-based fatigue life analysis of V- and rectangular-notched specimens under identical material and loading conditions.
- To identify which notch geometry parameters most strongly influence stress localisation and fatigue life by using a Taguchi L9 design coupled with ANOVA, and to rank their relative influence for each notch configuration.
- To translate the combined experimental and numerical findings into practical guidelines for notch-sensitive design, offering design-relevant recommendations for fatigue-critical components used in marine, biomedical, and structural applications.

2 Materials and methods

2.1 Material

AISI 316L which is an austenitic stainless-steel was chosen owing to its remarkable corrosion resistance, superior ductility, and extensive utilization in fatigue-sensitive domains including marine infrastructure, biomedical implants, and chemical processing environments. Its ultra-low carbon content (below 0.03%) plays a crucial role in suppressing sensitization during thermal cycles such as welding, thereby preserving its mechanical integrity under cyclic stress conditions. The chemical composition of AISI 316L is mentioned in Table 1 [8].

Table 1. Chemical composition of AISI 316L.

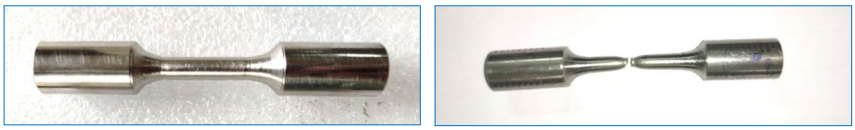
Element	Composition (wt.%)
C	0.02
Cr	16.613
Mn	1.238
Mo	2.09
Ni	10.19
P	0.04
S	0.01
Si	0.468
Fe	Balance

2.2 Experimental and simulation works undertaken

A hybrid approach, combining experimental tensile testing with FEM-based fatigue analysis, was adopted to improve the accuracy of life prediction for notched AISI 316L specimens. The mechanical properties obtained from tensile tests were used as input for the ANSYS fatigue module, thereby increasing the reliability of the predicted fatigue lives. The developed framework makes it possible to represent stress concentration effects with high fidelity and to obtain fatigue life estimates that are strongly responsive to geometry. Such capability is essential when designing components that must resist fatigue damage while operating under demanding service conditions.

2.3 Tensile testing

Tensile testing was performed to experimentally determine the UTS of AISI 316L stainless steel, which served as critical inputs for both the finite element (FE) material model and fatigue life prediction. Tensile testing was performed using a 100 kN computerized Universal Testing Machine (UTM), supplied by Fine manufacturing group. The tests were conducted under quasi-static loading conditions in accordance with ASTM E8/E8M standards. Cylindrical tensile specimens were precisely machined using a CNC lathe and the tensile tests were performed. Critical dimensions like gauge length and diameter were held within ±0.02 mm and ±0.01 mm, respectively. Smooth surface finish was ensured for the specimens and all dimensions were verified using a calibrated micrometer, post fabrication. A sample tensile testing specimen before and after failure is presented in Figure 1 and the UTM employed is shown in Figure 2.



(a) (b)

Fig. 1. Tensile testing specimen, (a) Before failure, and (b) After failure.

Fig. 2. UTM employed for tensile testing.

2.4 Fatigue specimen geometry

The fatigue specimen is designed as per the ASTM E606/E606M standard (Standard Test Method for Strain-Controlled Fatigue Testing) and its dimensional details are presented in Figure 3.

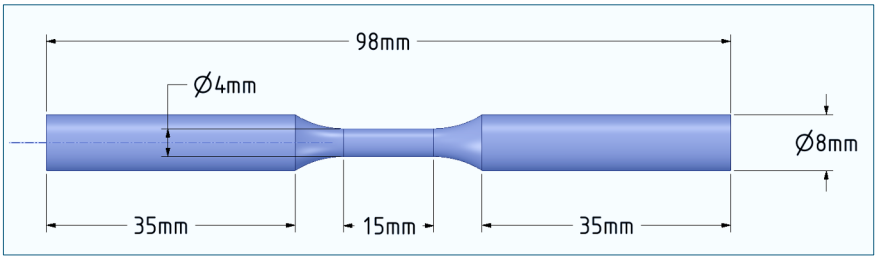


Fig. 3. Geometry of the fatigue specimen.

2.5 Notch configurations and experimental design

To enable a comparative fatigue analysis, two distinct notch geometries V-notch and rectangular notch were introduced symmetrically at the mid-span of the gauge length. The rationale behind selecting these geometries lies in their omnipresence in engineering components. V-notches mimic sharp defects such as cracks or weld toes, while rectangular notches resemble machined cutouts or grooves. V-notches and rectangular notches of different dimensions were created at the mid of the gauge length of the fatigue specimen. The design of experiments was carried out as per the Taguchi L9 orthogonal array and the notch parameters/ factors varied along with their levels are presented in Table 2.

Table 2. Notch parameters and their levels used in the Taguchi design.

Notch Parameter (notation)	Units	Level		
		Low	Medium	High
Width (w)	mm	1	1.25	1.5
Depth (d)	mm	0.5	0.75	1
Notch Central Angle (a)	degrees	120	240	360

The dimensional details of the notches as per the chosen experimental array are presented in the Table 3.

Table 3. Taguchi L9 Array employed.

Run	w	d	a
1	1	0.5	120º
2	1	0.75	240º
3	1	1	360º
4	1.25	0.5	240º
5	1.25	0.75	360º
6	1.25	1	120º
7	1.5	0.5	360º
8	1.5	0.75	120º
9	1.5	1	240º

2.6 Solid modelling of the specimens

Solid modelling of the specimens is carried out in SolidWorks and the models are imported into ANYSY 18.1 as IGES files. Post import, the un-notched specimen is presented in Figure 4, while representative V-notched and rectangular notched specimens are presented in Figure 5 and Figure 6 respectively.

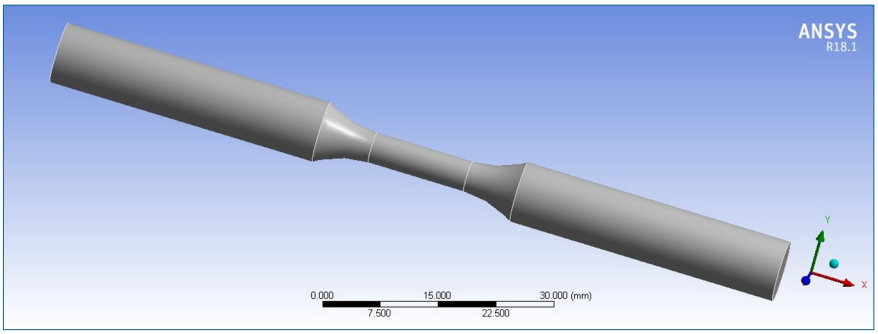


Fig. 4. Un-notched specimen.

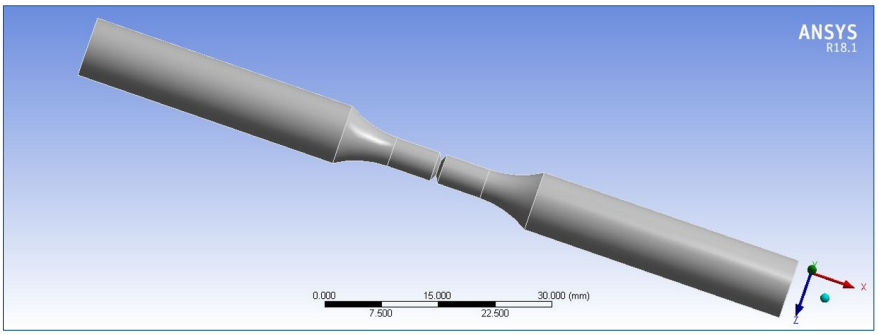


Fig. 5. A typical V-notched specimen.

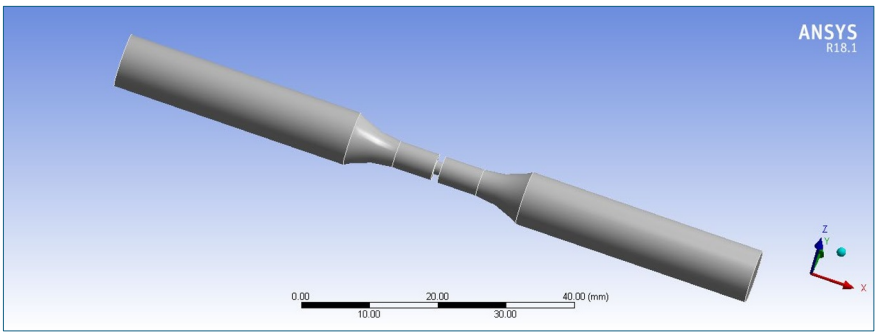


Fig. 6. A typical rectangular notched specimen.

2.7 Finite element modelling

To capture the localised stress-strain fields induced by geometric discontinuities, a high-fidelity FEM framework was developed using ANSYS Workbench 18.1. Each specimen, whether un-notched, V-notched or rectangular-notched, was digitally constructed according to the dimensional specifications outlined in Sections 2.4 and 2.5, using SolidWorks and

exported to ANSYS 18.1 as IGES file for meshing and analysis. Due to the complex curvature and sharp transitions inherent in notch profiles, quadratic tetrahedral elements (SOLID187) were utilized for spatial discretization. These 10-node elements offer superior capability in modelling irregular geometries and nonlinear stress gradients, making them ideal for simulating stress concentration phenomena in the vicinity of the notch root. A mesh convergence study was conducted prior to the final fatigue simulations. The primary objective was to determine the minimum element size required in the vicinity of the notch root, where stress and strain gradients are most severe, such that further refinement yields negligible changes in the calculated peak stress values. Starting with a coarse mesh which was of the default element size, successive refinements were applied for the elements of the entire specimen. Finally, the maximum possible mesh refinement, i.e., Level 3, was employed owing to the small geometry of the specimen. The ANSYS solver automatically produced very fine elements at the notch root and coarser elements away from the notch. In short, the advantage of analyzing the small specimen geometry was exploited during the discretization process. A systematic convergence check was then performed by comparing the maximum von Mises stress at the notch root as the refinement level was increased from 1 to 3. In the case of rectangular notch of Run 1, the change in peak stress between Levels 2 (540.31 MPa) and 3 (548.97 MPa) was found to be at 1.6%, indicating that further refinement would not significantly alter the local stress results. This confirmed that the Level 3 mesh provides a mesh-independent estimate of the notch-root stresses and, consequently, reliable inputs for the subsequent fatigue-life calculations.

2.8 ANSYS fatigue tool

To estimate the fatigue life of the notched AISI 316L specimens, the built-in ANSYS Fatigue Tool was employed in conjunction with the static structural simulation results. This tool facilitates fatigue life assessment by integrating material response, stress/strain history, and mean stress correction models within a unified computational framework. The fatigue life evaluation was carried out using the strain-life (ε–N) approach, particularly suited for capturing fatigue initiation under localized plastic deformation, a phenomenon pronounced at notch roots. The Smith-Watson-Topper (SWT) model was selected as the fatigue damage criterion, as it effectively combines the damaging effects of mean stress and strain amplitude, and has shown high predictive accuracy for ductile materials like AISI 316L under multiaxial and non-proportional loading. Material fatigue properties such as strength coefficient, ductility coefficient, strength exponent, and ductility exponent were computed from the experimental tensile testing results. A constant load frequency was assumed in the study to isolate the geometric effects of the notches on the fatigue life.

3 Results and discussion

Firstly, tensile testing was carried out to investigate the UTS of the material as it was needed to compute other fatigue properties. The average UTS of AISI 316L from five trials was observed to be 719 MPa which was subsequently used to compute other fatigue parameters of the material. A new material to represent AISI 316L was created in ANSYS material library with the required properties and the fatigue parameters applied for the FEM-based fatigue analysis in ANSYS are tabulated in Table 4 [9].

Table 4. Fatigue parameters of AISI 316L used in ANSYS.

Fatigue Parameter	Value
Strength Coefficient	1078.5 MPa
Strength Exponent	-0.087
Ductility Coefficient	0.59
Ductility Exponent	-0.58
Cyclic Strain Hardening Exponent	0.15
Cyclic Strength Coefficient	1167.21 MPa

Figure 7 illustrates the FE model with applied boundary conditions that replicate a uniaxial cyclic loading scenario. A uniform pressure of 55 MPa was applied axially at one end of the specimen and the opposite end was subjected to a fully constrained boundary condition i.e. all translational and rotational degrees of freedom were restricted to serve as a rigid anchor. Same boundary conditions were applied consistently to all notched specimens as well to quantitatively record the detrimental effect of the notch geometry on the fatigue life. The magnitude of the pressure is arrived at, by iteratively analyzing different values on the specimens. The magnitude of 55 MPa yielded infinite fatigue life in the un-notched condition and significantly less life in case of notched conditions. Therefore, this stress level was uniformly applied across all models to enable consistent comparison. A sinusoidal load waveform was simulated using static equivalent peak stress levels, with a fully reversed stress ratio (R = -1).

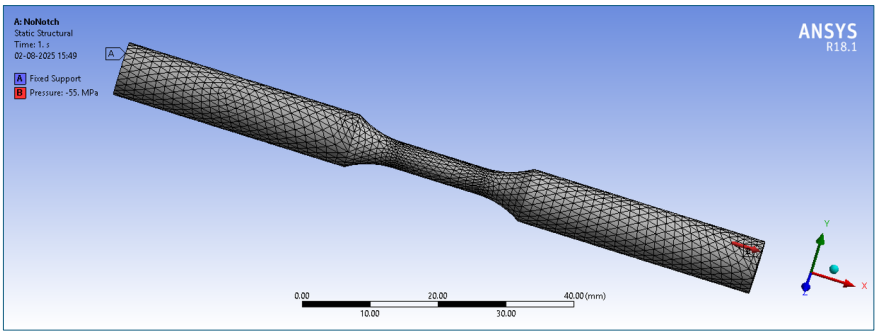


Fig. 7. FE model with the applied boundary conditions.

The results obtained from the FEM and fatigue life estimations were critically analyzed to elucidate the influence of notch geometry, specifically width (w), depth (d), and central angle (a), on the fatigue performance of AISI 316L stainless steel under cyclic axial loading. The un-notched specimen served as a control to benchmark fatigue resistance in the absence of geometric discontinuities. Under the applied loading conditions, it exhibited a peak stress of 228.91 MPa (Figure 8) with theoretically infinite fatigue life (> 10^6 cycles), as no significant local plasticity or stress concentration was induced. This validates the material's high endurance capacity in the absence of notches and sets the foundation for comparative analysis. The fatigue life of the un-notched specimen is 29839000 cycles as depicted in Figure 9 and this can be treated as infinite life as per standard fatigue literature [10]. The von-Mises stress and fatigue results of the un-notched specimen are tabulated in Table 5. The endurance limit of the material is around 300 MPa which is much higher than the induced stress in the material and this substantiates the infinite fatigue life recorded [11].

Table 5. Results of un-notched specimen.

Scenario	von-Mises Stress (MPa)	Fatigue Life (cycles)
No Notch	228.91	29839000 (Infinite fatigue life as it is > 10^6)

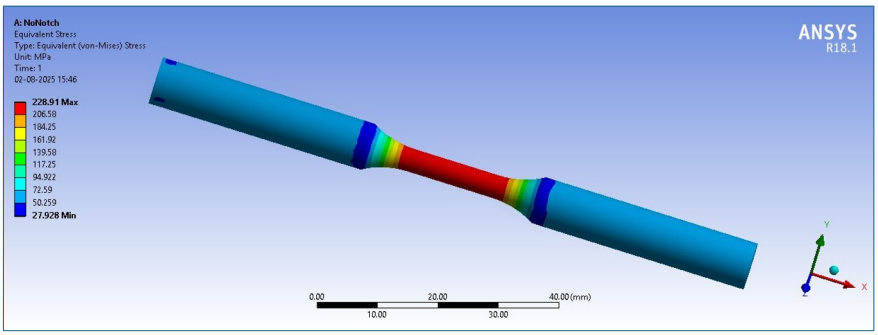


Fig. 8. Von-Mises Stress distribution in un-notched AISI 316L specimen.

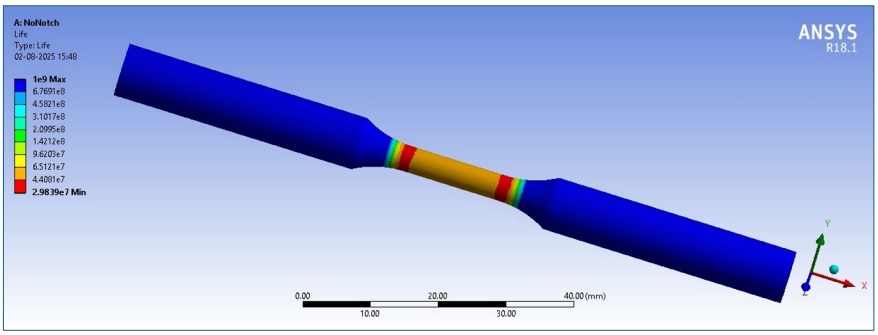


Fig. 9. FEM-based fatigue life estimation of un-notched specimen.

The fatigue results of the notched specimens are presented in Table 6 and they prove the fact that the introduction of V-shaped and rectangular notches led to noticeable amplification in peak stresses at the notch root, ranging from approximately 549 MPa to 2262 MPa. V-notches consistently exhibited higher stress concentrations compared to rectangular notches for equivalent geometric parameters, owing to their sharper curvature and reduced notch radii. The most extreme case was observed for the V-notch specimen with w = 1.5 mm, d = 1 mm, and a = 240°, which recorded a peak stress of 2262.3 MPa, nearly 10X higher than the un-notched specimen. A consistent trend was observed wherein rectangular notches demonstrated significantly longer fatigue lives than their V-notched counterparts under identical conditions. Run 1 as an instance, rectangular notch with w = 1 mm, d = 0.5 mm, a = 120°, lasted 17,720 cycles. However, the matching V-notch broke much sooner at 4,081 cycles. The reason lies in shape driven differences, where flat bottomed notches allow wider plastic deformation zones along with smoother stress flow, thus reducing localized deterioration. On the flip side, pointed V-shaped cuts focus strain into a tiny region near the edge, boosting chances for early microcrack formation plus rapid progression under load repetition. Such trends become especially clear when angles increase sharply, around 360°, where intense stress peaks push materials toward sudden breakdown. In most test setups, rectangular notches lasted longer than V-notches. However, in Test 3, the rectangular version performed just a bit worse compared to the V-shaped. This dip in performance relates to its deeper, narrower shape, leading to more focused stress and less room for plastic deformation. Because of this, typical ways that rectangular notches spread out stress no longer worked well. The stress could not sufficiently diffuse into the surrounding material, resulting in localized plasticity and intense strain accumulation near the base corners. Conversely, the V-notch with the same depth and angle, although geometrically sharp, allowed for a more favourable stress gradient along the flanks, reducing the severity of localized damage in this

specific case. Hence, the marginally higher fatigue life observed in the V-notch under Run 3 can be viewed as a consequence of unfavourable geometric proportions in the rectangular notch that nullified its typical stress redistribution advantage. The stress distribution and fatigue life of Run 3 with rectangular notch are presented in Figures 10 and 11, respectively. The total strain distribution within the notch of Run 3 for V- and rectangular notches are presented in Figures 12 and 13, respectively. It is clearly evident that there are more locations and wider zones with maximum strain (approx. in the range of 0.007-0.008) in the case of rectangular notch when compared to the V-notch due to the aforesaid reasons. This corroborates the marginally more fatigue life in the case of V-notch when compared to the rectangular notch.

Table 6. Fatigue results of the notched specimens.

Run	w	d	a	V-Notch		Rectangular Notch	
				Stress (MPa)	Fatigue Life (cycles)	Stress (MPa)	Fatigue Life (cycles)
1	1	0.5	120º	738.04	4081	548.97	17720
2	1	0.75	240º	1320.9	417	995.37	1183
3	1	1	360º	1364	372	1400.3	339
4	1.25	0.5	240º	1330.2	406	582.6	12837
5	1.25	0.75	360º	1030.1	1037	874.65	1977
6	1.25	1	120º	1049.6	966	842.06	2312
7	1.5	0.5	360º	980.55	1254	620.32	9290
8	1.5	0.75	120º	1004.9	1140	782.1	3163
9	1.5	1	240º	2262.3	68	1338.2	398

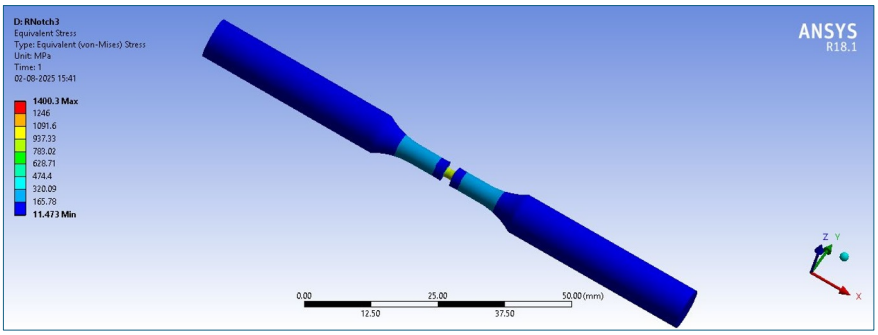


Fig. 10. Von-Mises stress in rectangular notch of run 3.

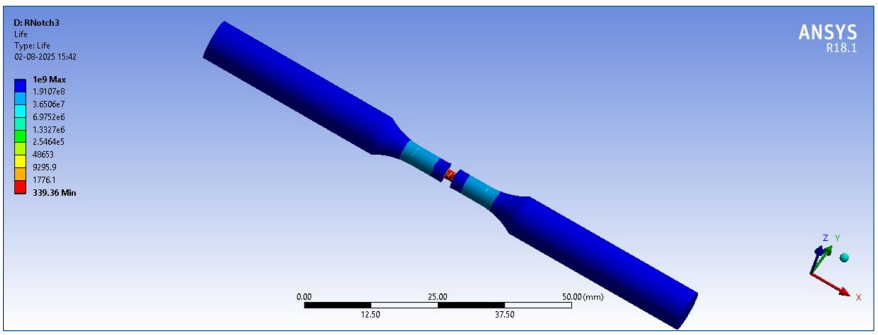


Fig. 11. Fatigue Life for specimen with rectangular notch of run 3.

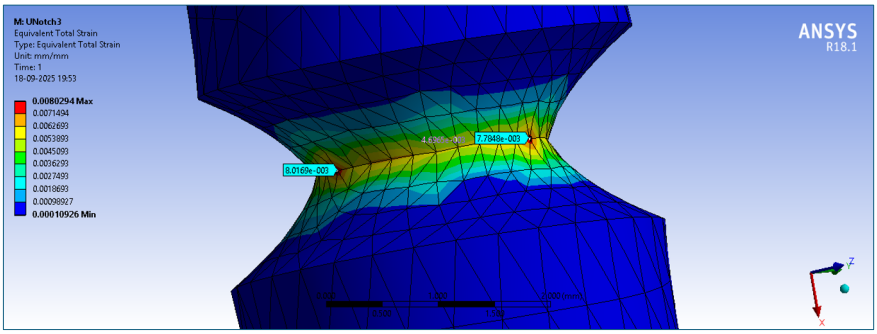


Fig. 12. Strain distribution within the notch of run 3 for V-notch.

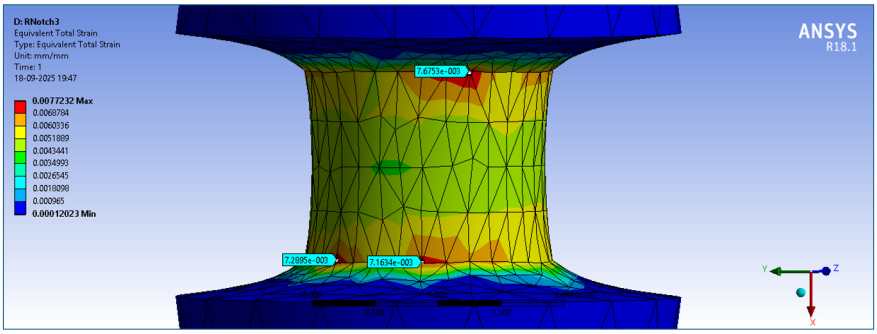


Fig. 13. Strain distribution within the notch of run 3 for rectangular notch.

3.1 Taguchi Analysis

To decode the underlying sensitivity of each notch parameter namely, width (w), depth (d), and central angle (a), on fatigue life, a Taguchi-based statistical analysis was performed. The mean fatigue life data from FEM were used to construct response tables for both V-notched and rectangular-notched specimens. The objective was to identify which geometric feature exerts the most dominant influence on fatigue degradation.

The response table (Table 7) as well as the Analysis of Means (ANOM) graph in Figure 14 for V-notches unequivocally demonstrates that there exists a dominance order for design variables, in which the central angle of the notch (a) is predominant, followed by depth (d) in the second place, and finally, width (w). A large value of delta for central angle (1765.3) is observed as opposed to other variables, proving that central angle is a major variable in governing stress intensity values at the tip of the notch. This is further supported by ANOVA analysis in Table 9, in which central angle occupies 42.23% of total variations.

In practice, when the notch angle gets narrower, stress concentration increases, causing cracks to start sooner during repeated loads. This matches fracture mechanics theory, since steeper shapes tend to raise localized stress levels, accelerating material breakdown over time. With V-shaped notches, their sharp tip naturally focuses on stress. Therefore, the opening angle turns into a critical variable needing precise management.

Table 7. Response table for means of fatigue life with V-notches.

Level	w	d	a
1	1623.3	1913.7	2062.3
2	803	864.7	297
3	820.7	468.7	887.7
Delta	820.3	1445	1765.3
Rank	3	2	1

For rectangular notches, notch depth (d) is the dominant factor that controls fatigue life. This is demonstrated by its large delta value of 12,266 in the response table (Table 8) and the ANOM plot (Figure 15). The ANOVA results in Table 10 further confirm this, indicating that the contribution of depth to the variation of fatigue life reaches as high as 87.27%. This is because the rectangular notch has a flat-bottom shape, which allows a wider zone for the distribution of local stresses. When the notch becomes deeper, the effective load bearing section decreases and localized strain amplifies, which in turn accelerates the fatigue process. The central angle ranks second in importance, suggesting that even though the rectangular notch is much less sharp than the V-notch, its angular geometry still dictates the local stress pattern. Width (w) is again the least important among these three factors, and its effect is almost insignificant.

This variation in rank order between V-shaped and rectangular cuts shows how much fatigue response depends on the specific shape of the cut. Although both interrupt an even distribution of stress, they achieve this through distinct mechanisms. Sharp V-cuts focus stress intensely at their tip, increasing maximum stress values. By contrast, rectangle-like cuts lead to larger areas undergoing plastic deformation while encouraging gradual strain accumulation across extended sections.

The Taguchi method used here delivers both a ranked list of factors from a statistical point of view and an intuitive sense of how shape elements affect fatigue performance in various notched forms. While some cases demand designs tailored to specific uses, others show that if acute corners are unavoidable, managing or reducing the angle at the center plays a key role. On the other side, with flat bottomed cuts made by machining, keeping the notch shallow turns out to matter most for longer service life. Overall, the Taguchi framework proves useful for prioritizing these design variables, and its utility is further enhanced when it is coupled with FEM-based fatigue simulations that resolve multiaxial stress states and localized plastic deformation near the notch root.

Table 8. Response table for means of fatigue life with rectangular notches.

Level	w	d	a
1	6414	13282	7732
2	5709	2108	4806
3	4284	1016	3869
Delta	2130	12266	3863
Rank	3	1	2

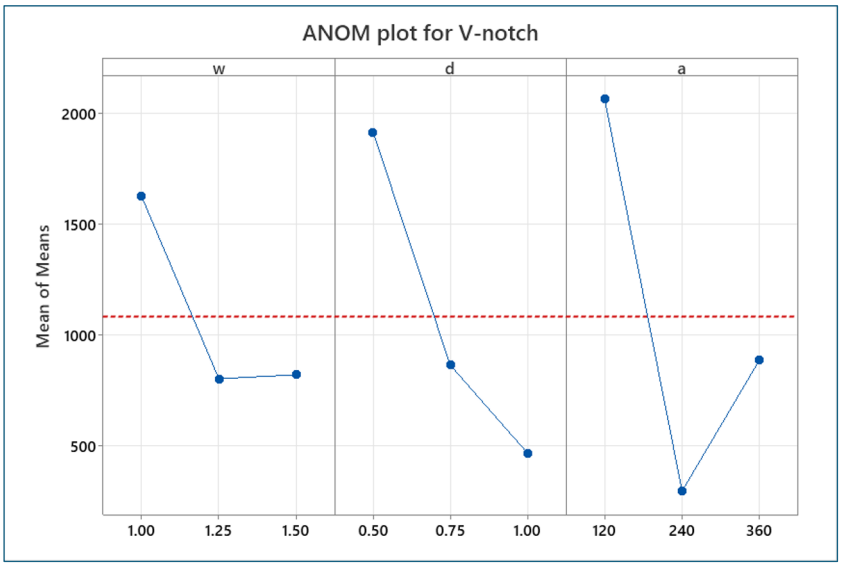


Fig. 14. ANOM plot for fatigue life with V-notches.

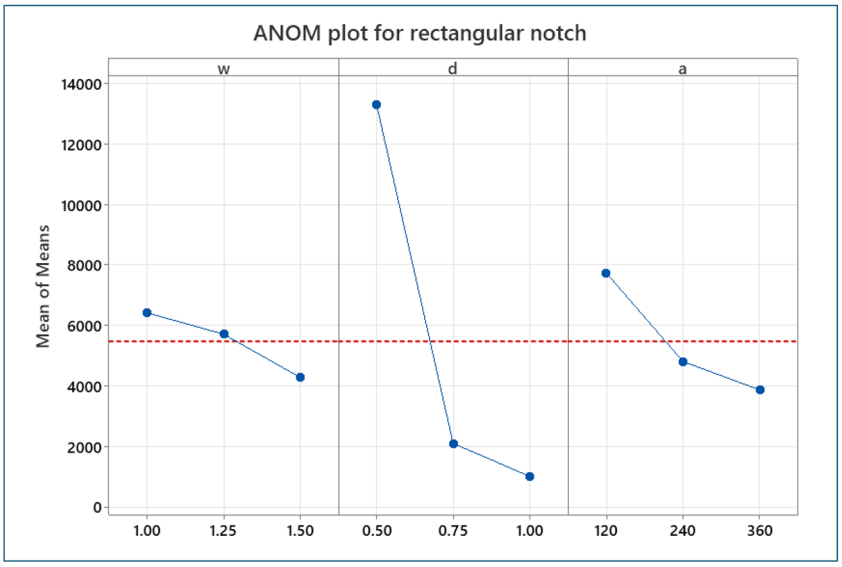


Fig. 15. ANOM plot for fatigue life with rectangular notches.

Table 9. ANOVA of fatigue life with V-notches.

Source	DF	SS	MS	% Contribution
w	2	1317533	658766	11.48
d	2	3345242	1672621	29.16
a	2	4845131	2422565	42.23
Error	2	1966021	983010	--
Total	8	11473926	--	--

Table 10. ANOVA of fatigue life with rectangular notches.

Source	DF	SS	MS	% Contribution
w	2	7066440	3533220	2.23
d	2	276518940	138259470	87.27
a	2	24360888	12180444	7.69
Error	2	8908284	4454142	--
Total	8	316854552	--	--

The parameter rankings obtained in this work agree well with earlier investigations on V- and rectangular notches. Together, they reinforce how strongly notch geometry shapes fatigue performance and offer quantitative guidance for designing components with improved fatigue resistance. As the FEM-based predictions are anchored to experimentally calibrated material data, the resulting framework is particularly effective for evaluating complex geometries where traditional analytical approaches become unreliable.

3.2 Limitations and future scope of the research

The present research provides significant contribution to the field of design engineering as it bridges a critical knowledge gap by clarifying how V-shaped and rectangular notch geometries control fatigue life in AISI 316L stainless steel. By integrating finite-element modelling with Taguchi experimental design, it delivers high-fidelity, design-relevant guidance for mitigating notch-induced failures. Its main limitation, however, is the reliance on an idealized constant-amplitude, fully reversed loading condition (R=-1) to isolate geometric effects. Hence it provides a baseline for comparison and does not fully represent the variable-amplitude cycles, corrosion-fatigue, and non-zero mean stresses typical of real service environments. The reported fatigue lives in this work should be viewed as baseline indicators rather than direct field predictions. Future research can experimentally test notched AISI 316L components in environments that introduce corrosion, surface roughness and typical manufacturing defects, and to subject them to variable-amplitude and mean-stress loading.

4 Conclusions

This study presents a hybrid experimental and FEM-based fatigue life evaluation of notched AISI 316L stainless-steel, drawing quantitative and mechanistic distinctions between V-notched and rectangular-notched geometries.

- The quantitative fatigue life results reveal a stark contrast between un-notched and notched AISI 316L specimens under identical cyclic loading conditions. The un-notched specimen, subjected to a peak stress of 228.91 MPa, exhibited an infinite fatigue life. Notched specimens showed a dramatic decline in fatigue life, with values ranging from 68 to 17,720 cycles.
- The most severe reduction was seen in the V-notch configuration of Run 9 (w: 1.5 mm, d: 1 mm, a: 240°), where the fatigue life dropped to 68 cycles, despite using the same material and loading scheme. This nearly five-order magnitude reduction compared to the un-notched case can be attributed to the intensified local stress and strain fields induced by the notch. The peak von-Mises stress for this specimen was 2262.3 MPa, approximately 10X higher than that observed in the smooth specimen. From an engineering-design perspective, the findings indicate that sharp V-notches should be avoided wherever feasible by introducing smooth radius transitions or blending features.

- Rectangular notches, while also detrimental, resulted in longer fatigue lives than V-notches in most of the cases. For instance, in Run 1 (w: 1 mm, d: 0.5 mm, a: 120°), the rectangular notch yielded a fatigue life of 17,720 cycles, compared to just 4,081 cycles for the corresponding V-notch. This improved performance is due to the rectangular notch's ability to facilitate broader plastic zone development, which promotes stress redistribution and delays crack initiation. The less aggressive curvature at the root of the rectangular notch reduces the severity of stress concentration compared to the cusp-like V-notch.
- ANOVA results showed that, for V-notches, the notch central angle accounted for 42.23% of the reduction in fatigue life. In contrast, depth was the most dominant factor by contributing 87.27% in the case of rectangular notches.
- The numerical results and supporting physical evidence show that even relatively small geometric discontinuities can severely reduce the fatigue life of AISI 316L, effectively turning a material that would otherwise exhibit an infinite-life into one that fails readily under cyclic loading. These findings highlight the need to limit notch severity and carefully tune geometric details during the design stage if extended fatigue life is to be achieved in service

Future research can expand this FEM approach by shifting from simplified steady-load models to actual tests on notched AISI 316L parts. Specifically, samples might undergo fluctuating loads, varying average stress states, or real-world factors like rust, uneven surfaces, or flaws left by production methods. These efforts may confirm earlier forecasts while improving them, also aiding creation of a broader lifespan prediction tool, that reflects how shape and operational wear interact in uses such as offshore setups, medical devices, or load-bearing systems.

References

1. P. P. Milella, "Chapter 11: Notch Effect," **in** *Fatigue and Corrosion in Metals*, pp. 479-518, Springer, ISBN. 978-3-031-51349-7, 2024. https://doi.org/10.1007/978-3-031-51350-3_11
2. Smith Salifu, Peter Apata Olubambi, "A review of fatigue failure and life estimation models: From classical methods to innovative approaches," *Science, Engineering and Technology*, vol. 4, no. 2, pp. 123-151, 2024. https://doi.org/10.54327/set2023/v4.i2.140
3. X. Xiao, V. Okorokov, and D. Mackenzie, "High cycle fatigue life assessment of notched components with induced compressive residual stress," *International Journal of Pressure Vessels and Piping*, vol. 206, Art. No. 105069, 2023. https://doi.org/10.1016/j.ijpvp.2023.105069
4. J. Zhang, J. Zhu, W. Guo, and W. Guo, "A machine learning-based approach to predict the fatigue life of three-dimensional cracked specimens," *International Journal of Fatigue*, vol. 159, Art. No. 106808, 2022. https://doi.org/10.1016/j.ijfatigue.2022.106808
5. W.-L. Ye, S.-P. Zhu, X. Niu, J.-C. He, and J. A. F. O. Correia, "Fatigue life prediction of notched components under size effect using critical distance theory," *Theoretical and Applied Fracture Mechanics*, vol. 121, Art. No. 103519, 2022. https://doi.org/10.1016/j.tafmec.2022.103519
6. M. Ma, X. Liu, X. Yu, and X. Wang, "Fatigue life prediction for notched specimen considering modified critical plane method," *Fatigue and Fracture of Engineering*

Materials and Structures, vol. 46, no. 3, pp. 1031-1044, 2023. https://doi.org/10.1111/ffe.13917

7. Abdulnaser M. Alshoaibi, Yahya Ali Fageehi, "Advances in Finite Element Modeling of Fatigue Crack Propagation," *applied sciences*, vol. 14, Art. No. 9297, 2024. https://doi.org/10.3390/app14209297
8. Jagadesh Kumar Jatavallabhula, Vaddi Venkata Satyanarayana, Vasudeva Rao Veeredhi, "Optimization of Fatigue Response in Notched AISI 316L Friction Welded Joints Using a Hybrid Entropy-VIKORTaguchi Approach," *International Journal of Engineering Trends and Technology*, vol. 73, no. 3, pp. 265-273, 2025. https://doi.org/10.14445/22315381/IJETT-V73I3P120
9. J. Jagadesh Kumar, "Fatigue analysis of friction welded notched marine steels," PhD Thesis, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), India, 2021.
10. T. Klabklay, C Sumpavakup, A Khumkrong, N Thasanavirud, P Pensuk, "Finite Element Analysis for Estimating Strength and Fatigue of the APM Structure," *E3S Web of Conferences*, vol. 602, Art. No. 01012, 2025. https://doi.org/10.1051/e3sconf/202560201012
11. N. Agarwal, H. Kahn, A. Avishai, G. Michal, F. Ernst, A.H. Heuer, "Enhanced fatigue resistance in 316L austenitic stainless steel due to low-temperature paraequilibrium carburization," Acta Materialia, vol. 55, pp. 5572-5580, 2007. https://doi.org/10.1016/j.actamat.2007.06.025
12. J. J. Kumar, G. Diwakar, and V. V. Satyanarayana, "Impact of notch geometry on the pressure bearing capacity of AISI 316L austenitic stainless steel under fatigue loading," *Universal Journal of Mechanical Engineering*, vol. 7, no. 6, pp. 336–347, 2019. https://doi.org/10.13189/ujme.2019.070605
13. J. K. Jatavallabhula, V. V. Satyanarayana, and V. R. Veeredhi, "Entropy-weighted TOPSIS Taguchi analysis of notch geometry on the fatigue performance of UNS S32760 grade stainless steel," *SSRG International Journal of Mechanical Engineering*, vol. 11, no. 6, pp. 82–91, 2024. https://doi.org/10.14445/23488360/IJME-V11I6P110