

Numerical simulation-driven design and cutting-force-validated evaluation of a large-diameter BTA trepanning tool for SS304L stainless steel

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**NUMERICAL SIMULATION-DRIVEN DESIGN AND CUTTING-FORCE-
VALIDATED EVALUATION OF A LARGE-DIAMETER BTA TREPPANNING
TOOL FOR SS304L STAINLESS STEEL**

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ABSTRACT

Large-diameter holes in power-generation, petrochemical, and nuclear components — such as reactor cooling pipes, heat exchangers, and pressure vessels — are increasingly produced by trepanning, which removes only an annular ring of material and therefore lowers the cutting force, power demand, and material loss relative to full-section machining. Standardised large-diameter trepanning-tool designs remain scarce, which limits process stability and forces application-specific solutions. Because SS304L is widely used in these components, this study presents a simulation-driven framework to design and evaluate a Boring and Trepanning Association (BTA)-type trepanning tool for SS304L, producing a 52.5 mm outer / 30 mm inner annulus. Two configurations were developed: a baseline design (Tool V1) and a load-balanced, stiffened design (Tool V2) with a reduced insert count and revised clearance geometry. Three-dimensional finite-element simulations using a Johnson–Cook material model predicted the transient cutting forces, which were validated experimentally with a Kistler 9257B multicomponent dynamometer on a purpose-built rig. The measured and predicted steady-state forces agreed to within approximately 9% for Tool V2 and approximately 20% for Tool V1. The validated forces were then applied in a structural finite-element analysis: relative to Tool V1, Tool V2 reduced the peak equivalent stress by approximately 69% and the total deformation by approximately 44%, indicating a stiffer and better-balanced load path, together with markedly improved cutting-force stability. The results demonstrate that a validated simulation workflow can discriminate between trepanning-tool geometries and guide the design of tools intended for large-diameter deep-hole service.

Keywords: BTA drilling; cutting-force validation; finite element analysis; SS304L; tool design trepanning

1. INTRODUCTION

Austenitic stainless steels of the 300 series are widely used in power generation, petrochemical processing, and nuclear systems because of their excellent corrosion resistance, mechanical stability, and reliability under high-temperature conditions. Among these, SS304L is widely used in nuclear reactor cooling pipes, heat exchanger components, and structural assemblies because of its low carbon content and resistance to intergranular corrosion [1, 2, 3]. Despite its superior service performance, SS304L poses major challenges in machining.

The material properties of SS304L, such as its ductility, strong strain-hardening behaviour, and poor thermal conductivity, create many difficulties in machining. The heat generated at the cutting tool–workpiece interface is difficult to dissipate, causing the cutting tool to operate at higher temperatures, wear out sooner, and produce poor surface integrity on the workpiece [4]. Deep-hole drilling adds to these difficulties through the inability to remove chips efficiently and the prolonged cutting period at the tool–workpiece interface [5]. Conventionally, large-diameter holes must be cut by removing the entire material profile, which creates a high thrust, requires large amounts of torque, and reduces the accuracy of the machined parts [6, 7]. Advanced deep-hole drilling techniques, such as BTA systems, have been widely adopted to overcome these limitations. BTA tools have internal coolant delivery, self-supporting guide pads, and mechanisms for controlling chip evacuation, all of which improve hole straightness and stability during machining [8, 9]. Analytical and experimental work has established that guide-pad interactions have a major effect on the accuracy of the hole diameter and on the ability of BTA tools to self-guide during drilling [10, 11]. Finite-element methods have also shown that the maximum stress concentrations and deformation in BTA tools occur in regions close to the cutting edges and at structural transitions [12, 13].

Trepanning is a more efficient alternative for generating large-diameter holes. This method removes only an annular ring of material while leaving a solid core intact; therefore, much less material needs to be cut away compared with standard techniques. Trepanning reduces the

volume of material removed and the associated total cutting force, as well as the power consumed, and leads to improved material utilisation and chip-removal ability compared with other methods [13, 14]. Mechanical models of trepanning have been established to predict cutting forces and torques during hole machining using finite-element methods. In addition, optimising the cooling fluid and chip-removal methods has been shown to improve process reliability when trepanning large-diameter holes in difficult-to-machine materials [14, 15].

Finite-element analysis has been established as an effective method for studying machining operations with complex material behaviour using numerical models [16]. The Johnson–Cook material model is widely used for finite-element analysis of stainless steels because it captures strain hardening, strain-rate sensitivity, and thermal softening during cutting [17]. Such models have been shown to predict cutting-force and thermomechanical behaviour reliably, which is essential for anticipating tool and workpiece response during machining.

A structural material such as AISI 4140 is typically selected for the tool holder because it offers good resistance to cyclic loading and maintains dimensional stability through repeated use [18]. This methodology allows researchers to simulate cutting forces and the structural behaviour of tool holders before physical testing, reducing both manufacturing time and cost by providing a simulated environment in which the cutting tool can be evaluated under representative operating conditions [19].

Although several studies have investigated BTA drilling systems, deep-hole boring, and trepanning processes independently, limited research has addressed the design and validation of integrated large-diameter trepanning tools for SS304L under industrial machining conditions [15]. In previous studies, the process mechanics, chip evacuation, or the structural aspects of tool design have generally been studied separately. In particular, the closest prior work develops a trepanning tool for stainless steel using a simulation approach [15]; the present study

differs in that it addresses a BTA-type, large-diameter (52.5 mm outer / 30 mm inner) annular geometry, couples transient finite-element force prediction with experimental force validation, and uses the validated forces as the basis for a comparative structural evaluation of two distinct tool configurations.

The geometry and load distribution of a trepanning tool significantly affect cutting stability, vibration behaviour, and dimensional accuracy during machining [20, 21]. Stress concentrations, deformation, and instability may be caused by imbalance in the cutting forces owing to poor positioning of the inserts and insufficient stiffness of the tool holder. The development of an efficient design method for the trepanning tool is therefore an important problem in current research [22, 23, 24].

An integrated experimental–numerical approach is proposed in the present study to address these limitations in the design and evaluation of BTA-based trepanning tools for SS304L. The effect of insert positioning, load balancing, and structural stiffness on machining performance was studied systematically, and two tool configurations were developed. Transient cutting forces were predicted by finite-element simulation and validated experimentally with a multicomponent dynamometer. The validated force data were then used in a structural analysis to evaluate the stress distribution and deformation behaviour of the two designs. It is emphasised that the experimental work was designed to validate the simulated cutting forces of the trepanning operation and not to demonstrate an extended-depth deep-hole trepanning process; deep-hole service is treated here as the target application for which the validated design methodology is intended.

The main contributions of this work are: (i) an integrated methodology combining transient force prediction, structural analysis, and experimental validation for the development of large-diameter trepanning tools; (ii) experimentally validated modelling of the transient cutting force

during BTA-based trepanning of SS304L; (iii) analysis of the effect of insert count, insert position, and clearance geometry on load distribution and structural robustness; and (iv) assessment of the performance improvement obtained through the optimised design, expressed as an approximately 69% reduction in equivalent stress and an approximately 44% reduction in deformation, indicating a stiffer, better-balanced load path.

2. MATERIAL AND METHODS

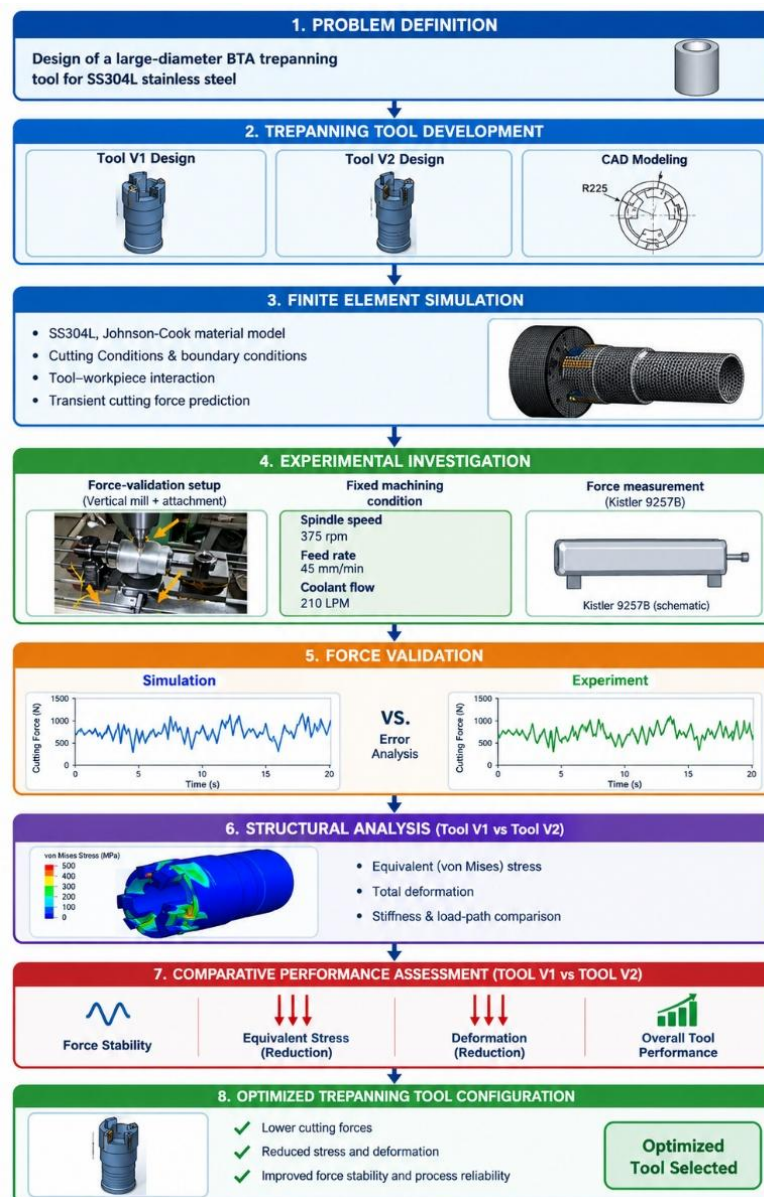


Figure 1 Integrated experimental–numerical methodology for the development and evaluation of the trepanning tool

2.1 Tool development

Two tool configurations based on the BTA system were proposed to study the effect of tool geometry, insert count and position, and structural rigidity on machining performance. Both configurations were designed to produce an annular cut with an outer diameter of 52.5 mm and an inner diameter of 30 mm. All inserts in both tools were of tungsten carbide with a nominal nose radius of approximately 250 μm and a zero rake angle; the two designs differ in their clearance angle and in the number and arrangement of inserts, as described below.

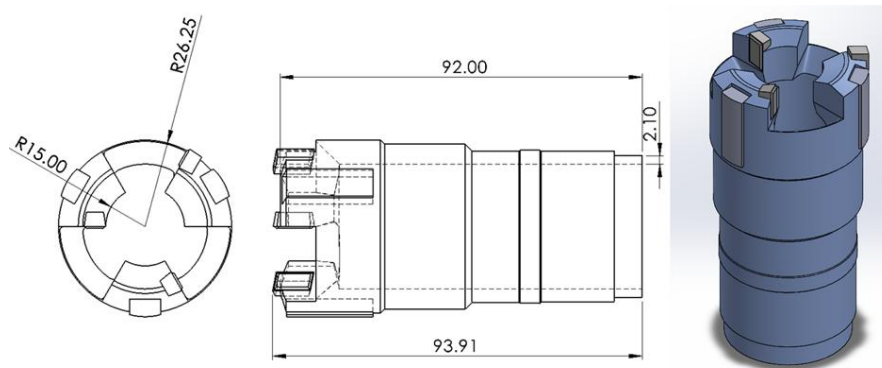


Figure 2 Tool V1 CAD design

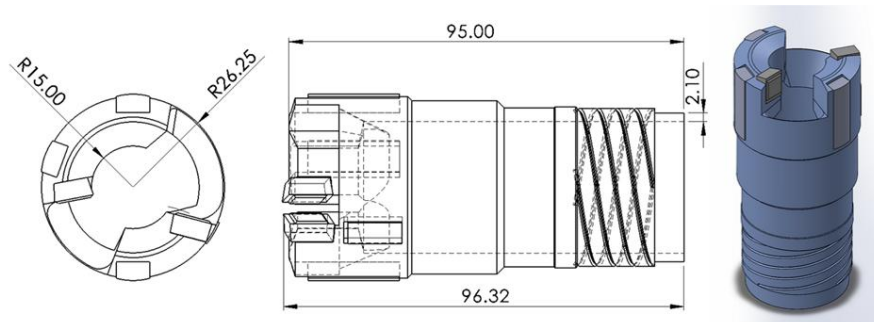


Figure 3 Tool V2 CAD design

The first configuration, Tool V1, was designed in accordance with conventional BTA principles. It employs three carbide inserts arranged in near-equispaced angular positions across the annulus and three guide pads. The inserts operate with a clearance angle of approximately 17°. No mid-radius insert is used; the inserts share the annular cut between them.

The guide pads are rectangular along the tool length and curved across their width, and internal channels for chip evacuation are provided in the tool body.

The second configuration, Tool V2, was developed to investigate the effect of improved load balancing and increased structural stiffness. Relative to Tool V1, Tool V2 uses two carbide inserts together with three guide pads, the two inserts being positioned close to guide pads that are oriented approximately 90° apart, so as to balance the radial cutting load against the pad reactions. The clearance angle was reduced to 13.5°, and the insert-pocket geometry and local wall thickness in the highly loaded regions were revised to improve the load paths from the inserts to the tool body. The machining dimensions (52.5 mm outer / 30 mm inner) were unchanged.

The two configurations were essential for a systematic study of the interplay between cutting-force evolution, structural behaviour, and stability during trepanning.

2.2 Finite-element simulation

A three-dimensional finite-element model was used to simulate the reaction forces generated during the trepanning process. The modelling approach and the boundary conditions applied to both tool configurations are shown in Figure 4.

The Johnson–Cook constitutive equation was used to model the behaviour of the workpiece material (SS304L) during cutting, as listed in Table 2. The tungsten-carbide cutting inserts were modelled as rigid bodies, whereas the tool holder was modelled with elastic properties corresponding to AISI 4140, as defined in Table 3. The properties of the tungsten-carbide inserts are summarised in Table 1.

The tool was operated at 375 rpm with a feed rate of 45 mm/min, the operating condition fixed from the preliminary trials described in Section 2.4. Tool–workpiece contact was defined using the Coulomb friction model.

A refined mesh was applied to the cutting zone to capture the local deformation and chip formation. The time-dependent force components (F_x , F_y , F_z) and torque were extracted from the simulations. The steady-state region of the force response was identified and used to determine the representative cutting loads for the structural analysis.

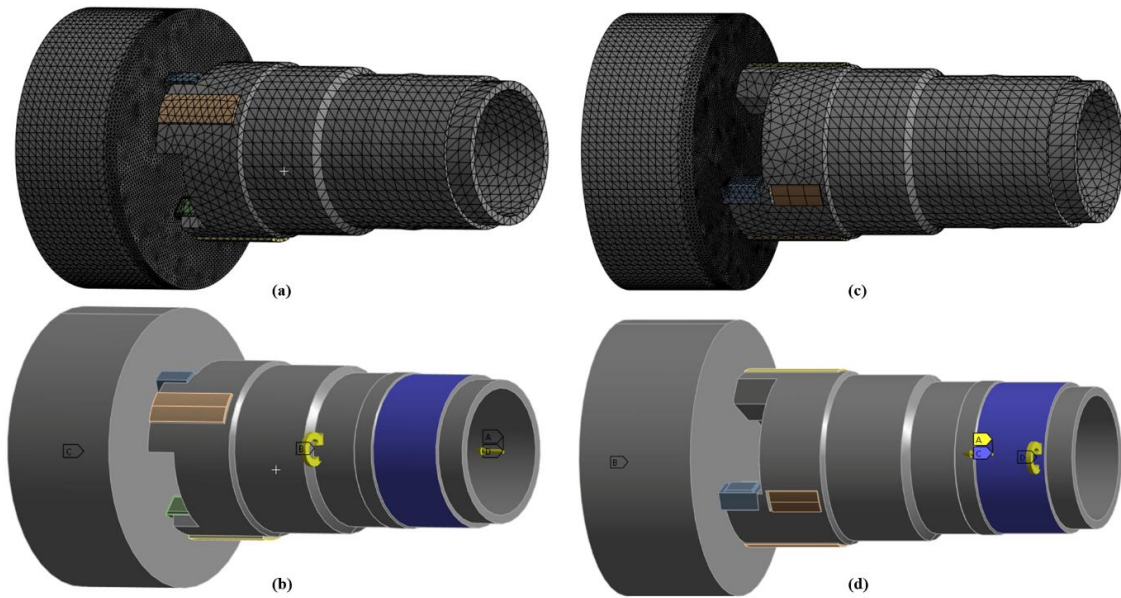


Figure 4 Finite-element model of (a) Tool V1 and (c) Tool V2 with boundary conditions on (b) Tool V1 and (d) Tool V2 for prediction of transient reaction forces

Table 1 Material properties of tungsten carbide [25]

Property	Value	Unit
Density	15000	kg m^{-3}
Young's modulus	650	GPa
Poisson's ratio	0.22	—

Table 2 Material properties of SS304L [6, 17]

Property	Value	Unit
Density	8000	kg m^{-3}
Young's modulus	193	GPa
Poisson's ratio	0.30	—
Isotropic thermal conductivity	16.2	$\text{W m}^{-1} \text{K}^{-1}$
Specific heat (const. pressure)	500	$\text{J kg}^{-1} \text{K}^{-1}$
Johnson–Cook: initial yield stress	215	MPa

Johnson–Cook: hardening constant	1000	MPa
Johnson–Cook: hardening exponent	0.45	—
Johnson–Cook: strain-rate constant	0.015	—
Johnson–Cook: thermal-softening exponent	1	—
Melting temperature	1673	K
Reference strain rate	1	s ⁻¹

Table 3 Material properties of AISI 4140 [18]

Property	Value	Unit
Density	7850	kg m ⁻³
Young's modulus	200	GPa

2.3 Structural analysis of tool configurations

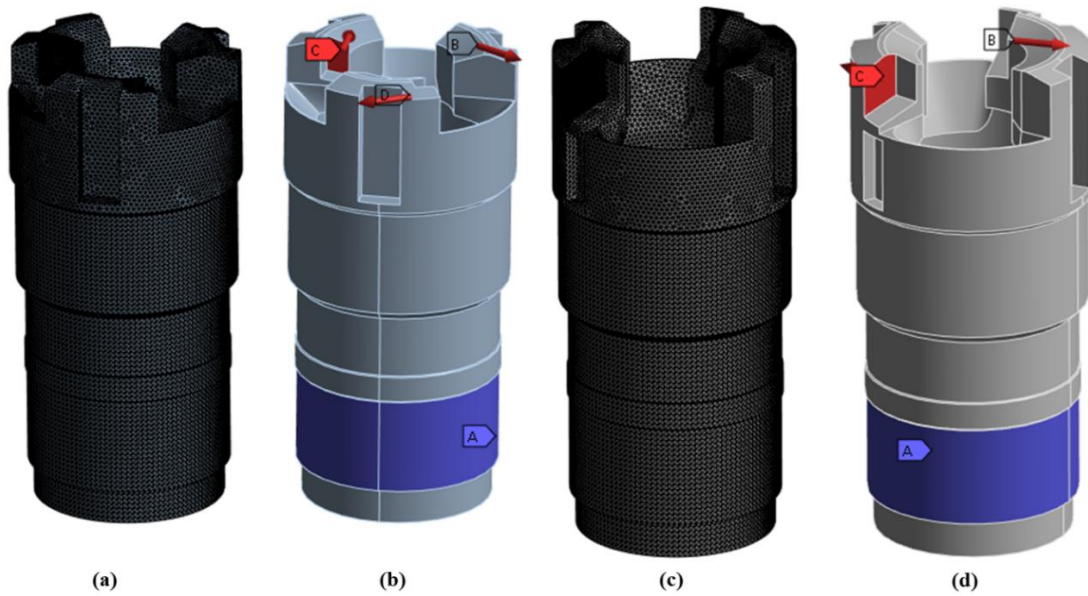


Figure 5 Finite-element model of (a) Tool V1 and (c) Tool V2 with boundary conditions on (b) Tool V1 and (d) Tool V2 for structural analysis

The structural analyses of both configurations are shown in Figure 5. The maximum steady-state reaction forces obtained from the force simulations were applied as external loads in the structural analysis.

The tool-holder interface was fixed in all degrees of freedom, as in the actual machining setup, allowing evaluation of the von Mises equivalent stress and total deformation. The regions of

interest were those near the insert pockets and geometric transitions, as these are susceptible to stress concentration.

2.4 Machining condition for the force-validation trials

The force-validation trials were conducted at a fixed operating condition established from preliminary trials rather than from a formal design of experiments. Spindle speed, feed rate, and coolant flow rate were explored over the ranges 350–425 rpm, 40–55 mm/min, and 210–240 LPM, respectively, with surface roughness (requirement $R_a < 3 \mu\text{m}$) and process stability as the screening criteria. A spindle speed of 375 rpm, a feed rate of 45 mm/min, and a coolant flow rate of 210 LPM produced the most stable cutting behaviour together with an acceptable surface finish, and this condition was used for both the numerical and the experimental force analysis.

2.5 Experimental force measurement

The experimental trials were designed solely to validate the finite-element cutting-force predictions under representative cutting conditions, and not to reproduce a full deep-hole trepanning operation. Because the present rig does not incorporate the internal chip-evacuation passages and high-pressure through-tool coolant delivery required for extended-depth machining, the validation cut was limited to an engagement depth of approximately 8 mm (a depth-to-diameter ratio of about 0.15). At this engagement, the instantaneous chip cross-section, and hence the steady-state cutting force is representative of that developed at greater depths, which makes the setup suitable for force-model validation. Guide-pad/bore-wall interaction, chip-transport drag, and thermal accumulation, which are specific to extended-depth machining, were therefore outside the scope of the experimental validation.

The trials were carried out on a vertical milling machine (Batliboy make). A purpose-built attachment was fabricated to mount in the machine arbor and to house the trepanning tool, so

that the simulated forces of the trepanning operation could be reproduced and measured. The setup is shown in Figure 6.

A Kistler Type 9257B three-component piezoelectric platform dynamometer was used to measure the cutting-force components. This non-rotating table dynamometer comprises four three-component quartz sensors preloaded between a base plate and a 100×170 mm top plate, with a measuring range of approximately ± 5 kN in F_x and F_y and up to 10 kN in F_z , and a natural frequency of about 2.3 kHz. It was coupled to a Type 5167A charge amplifier. The SS304L workpiece was clamped on the dynamometer, which was fixed to the machine table to ensure repeatability. The force components along the X, Y, and Z axes were recorded during the trepanning operation, and the acquired signals were filtered to reduce high-frequency noise.

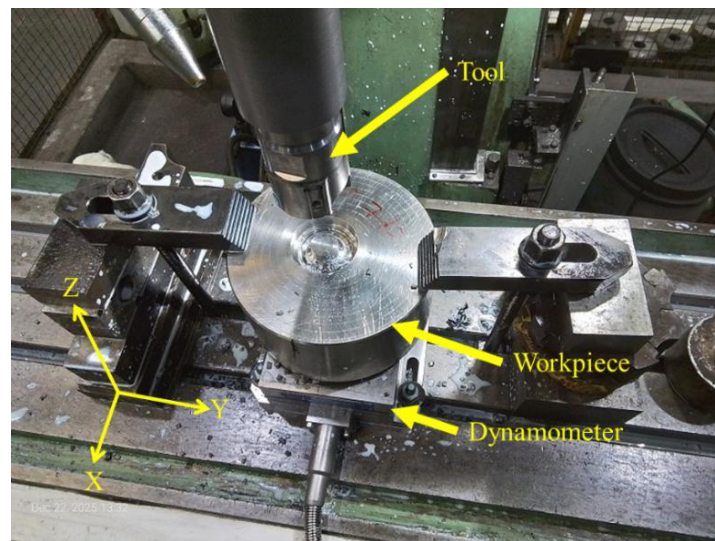


Figure 6 Experimental setup for reaction-force measurement on the vertical milling machine with the purpose-built trepanning attachment and the Kistler 9257B dynamometer

The steady-state cutting forces were determined from the filtered data and compared with those obtained from the numerical simulation.

3. RESULTS AND DISCUSSION

3.1 Evolution of cutting forces and validation

The evolution of the cutting forces from simulation (SFx, SFy, SFz, SMz) and experiment (EFx, EFy, EFz, EMz) is shown in Figures 7 and 8 for Tools V1 and V2, respectively.

Both data sets show a similar trend: an initial rise in force as the tool engages the workpiece, followed by a near-constant state under stable chip removal. The maximum forces recorded for Tool V1 are significantly larger than those for Tool V2, and the variations in Fx, Fy, Fz, and Mz are also larger for Tool V1.

Tool V2 exhibited noticeably smaller peak cutting forces and a more stable force progression. This improvement is linked to the enhanced load transfer of the modified design: the revised insert arrangement reduced the radial force imbalance and distributed the load on the cutting edges more evenly.

The reduced force fluctuation of Tool V2 indicates higher dynamic stability. A stable force progression is particularly important in trepanning because it helps to avoid vibration.

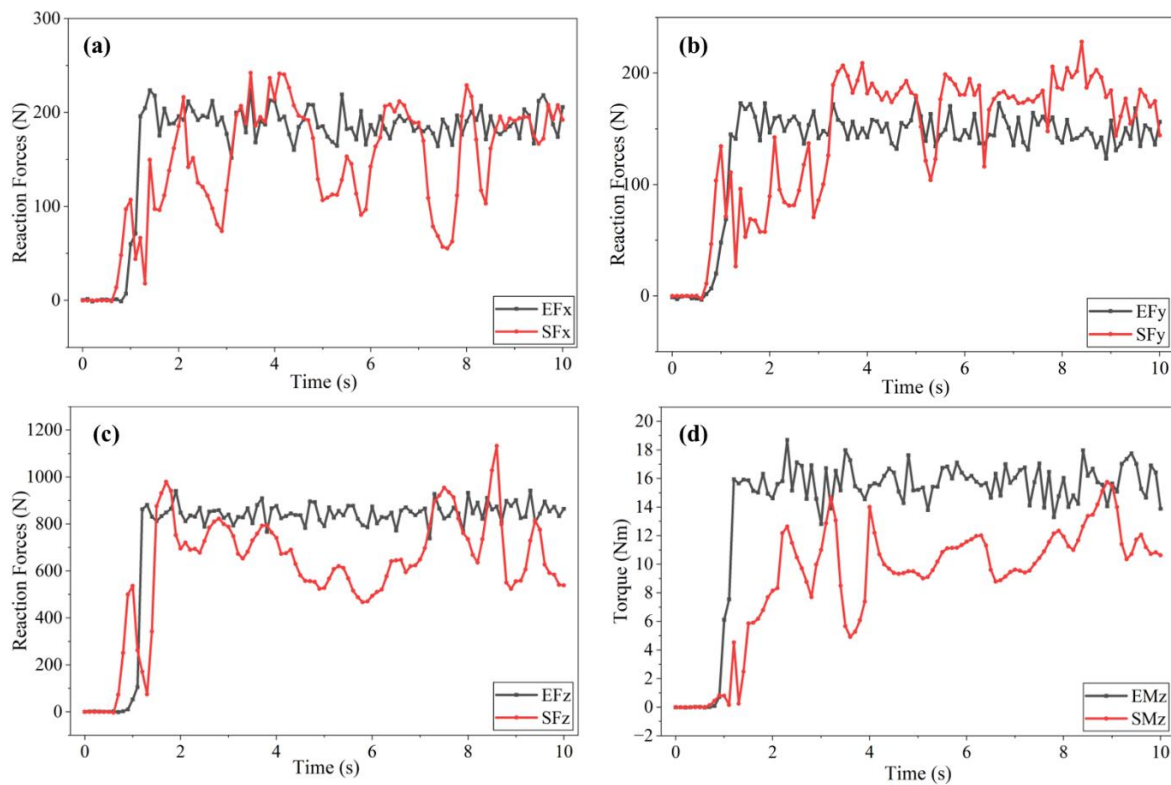


Figure 7 Reaction forces (a) Fx, (b) Fy, (c) Fz, and (d) torque for Tool V1

The numerical simulations reproduced the experimental data in the steady-state region; the minor deviations in the peak values for each tool are attributed to friction-modelling approximations and to experimental factors such as machine compliance and slight tool misalignment.

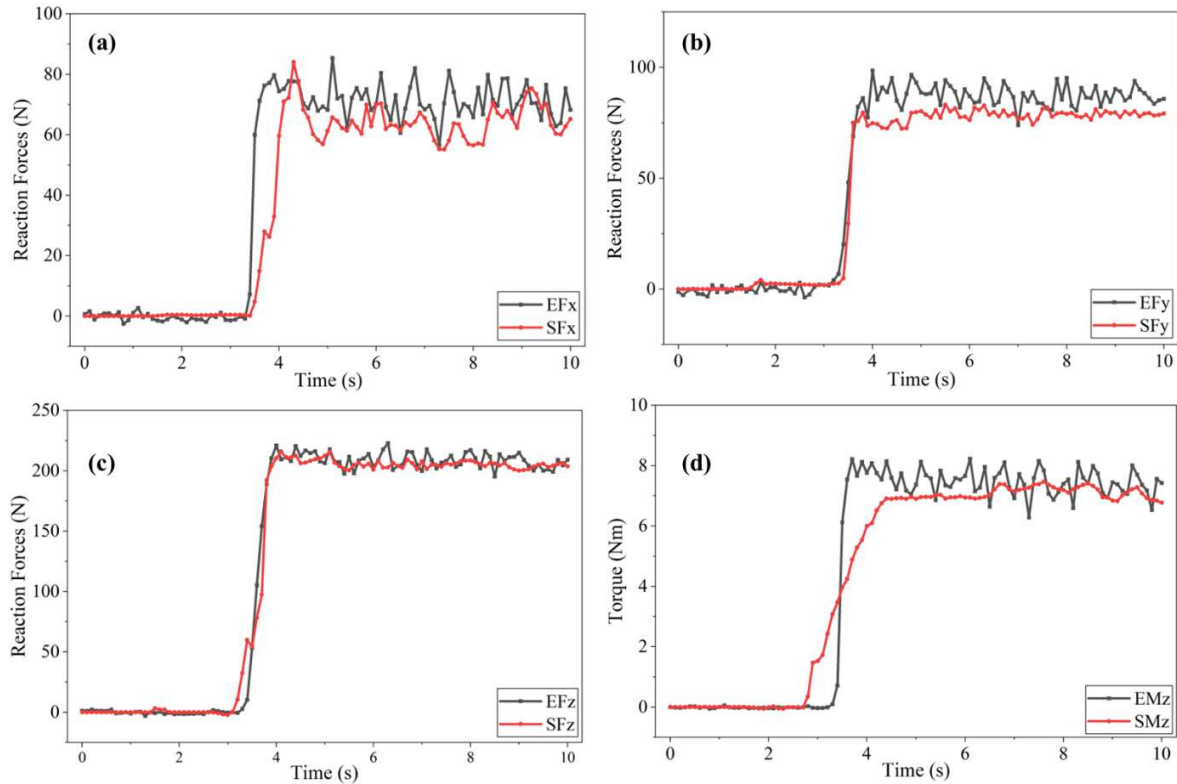


Figure 8 Reaction forces (a) Fx, (b) Fy, (c) Fz, and (d) torque for Tool V2

3.2 Validation and error analysis

The numerical predictions agreed well with the experimentally measured cutting forces in the steady-state regime. The average difference between the numerical and experimental results was about 20% for Tool V1 and much smaller, about 9%, for Tool V2. The smallest difference was found for the cutting force in the z-direction (Fz). The larger deviations in the lateral force components and torque are attributed to practical factors — machine-tool compliance, insert wear, friction-modelling assumptions, slight tool misalignment, and vibration — that were not fully captured in the numerical model.

The reduced deviation for Tool V2 reflects the improved force stability and predictability of the cutting process arising from the better load balancing and stiffness of the tool structure.

3.3 Structural response of the trepanning tools

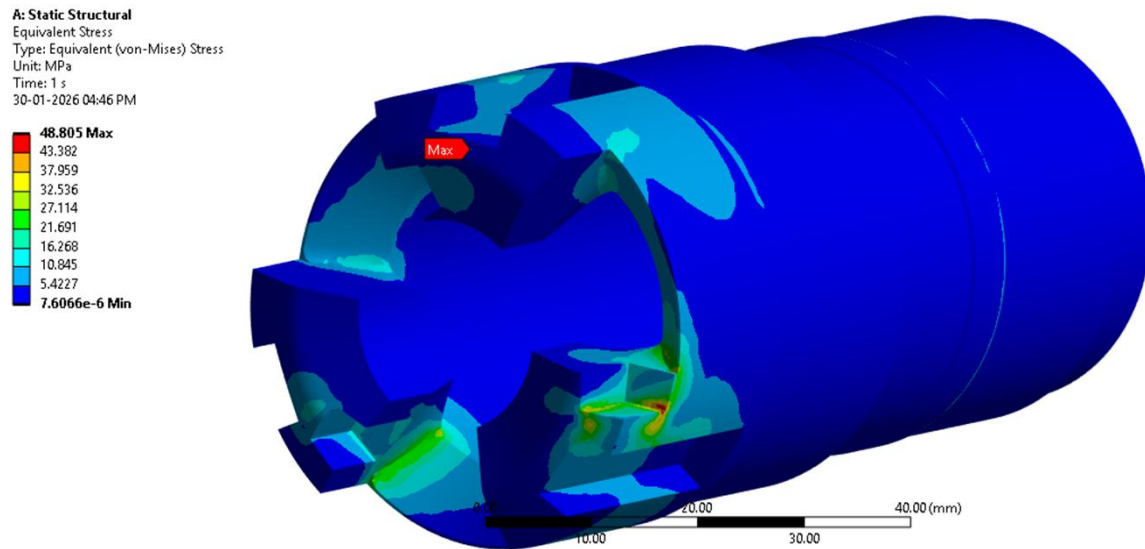


Figure 9 Equivalent stress in Tool V1

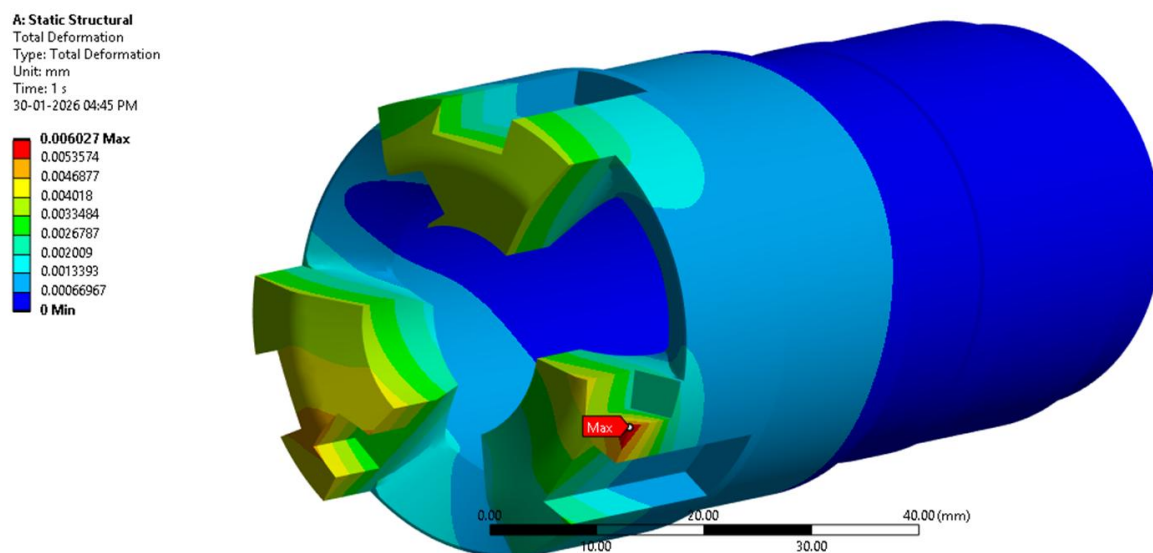


Figure 10 Total deformation in Tool V1

For Tool V1, the equivalent-stress result (Figure 9) shows a maximum stress of about 48.8 MPa, and the total deformation (Figure 10) is about 0.0060 mm. For Tool V2, the maximum

equivalent stress decreases to about 15.2 MPa (Figure 11) and the total deformation to about 0.0034 mm (Figure 12).

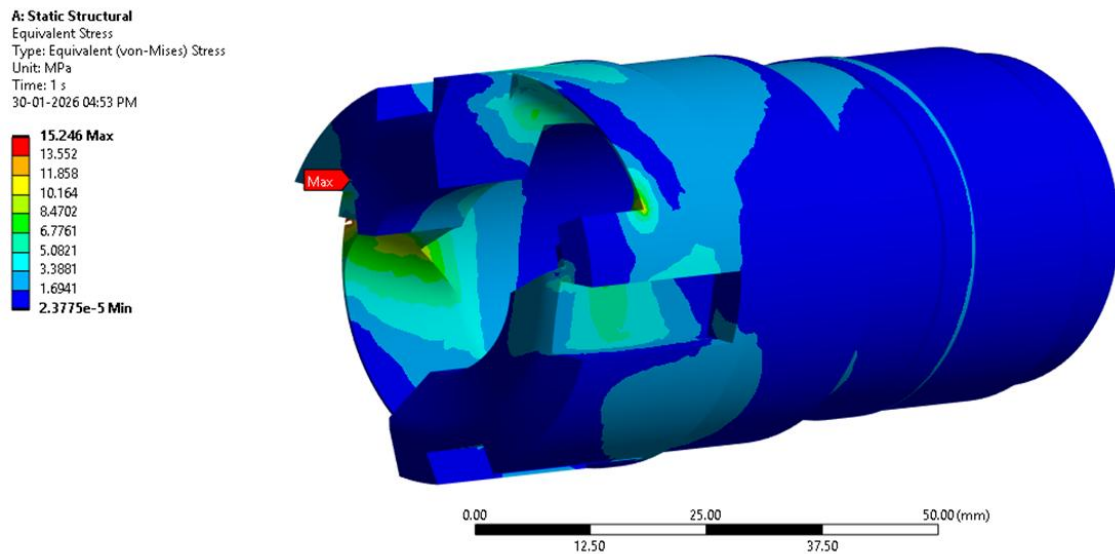


Figure 11 Equivalent stress in Tool V2

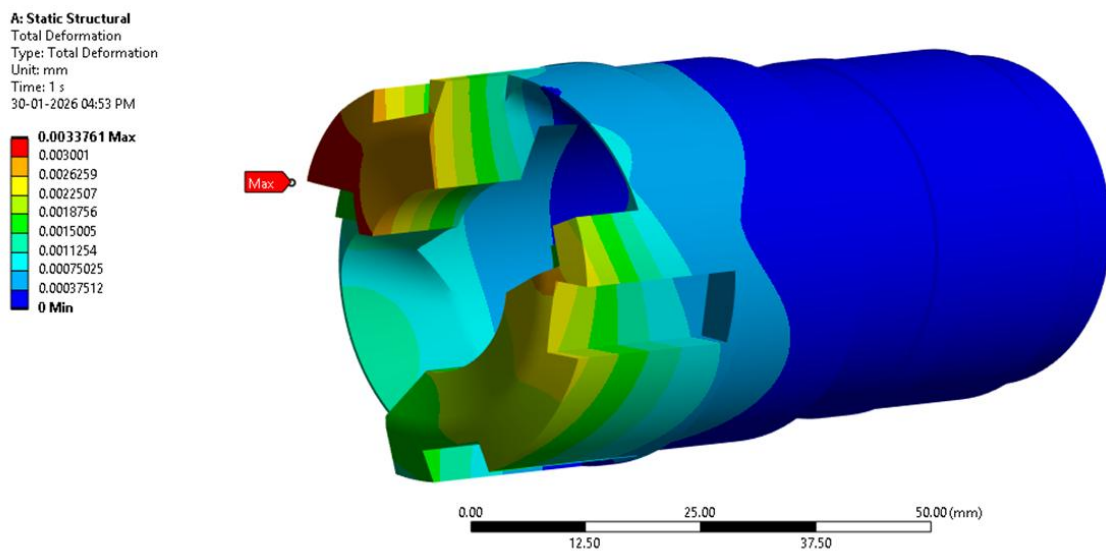


Figure 12 Total deformation in Tool V2

It should be noted that the absolute stresses and deformations are small for both tools, and both remain far below the yield strength of the AISI 4140 tool-holder material; neither design is therefore anywhere near structural failure. The significance of the comparison lies not in the

absolute magnitudes but in the relative improvement: the approximately 69% lower equivalent stress and approximately 44% lower deformation of Tool V2 indicate a stiffer structure and a better-balanced transfer of the cutting load from the inserts to the tool body. In Tool V1, localised stress concentrations developed near the insert pockets because of non-uniform force transmission and insufficient structural support in the heavily loaded regions.

In Tool V2, the modified geometry improved the transfer of the cutting load from the inserts to the tool body, reducing the stress-concentration factors and lowering the deformation. This higher stiffness is important for dimensional accuracy and stability during machining, and together with the improved force stability reported is the practically relevant benefit of the optimised design.

3.4 Relationship between cutting forces and structural performance

A direct link was observed between the cutting-force behaviour and the structural response. The larger force fluctuations of Tool V1 are associated with localised stress concentration and increased deformation, whereas the smoother force profile of Tool V2 is associated with a more uniform stress distribution and improved structural stability.

This relationship demonstrates the importance of balancing the cutting forces when designing the tool. By optimising the insert arrangement and the structural geometry, both the cutting performance and the mechanical reliability can be improved.

3.5 Design mechanics and industrial applicability

3.5.1 Mechanics of load balancing

The mechanics of load balancing are the main cause of the performance difference between Tool V1 and Tool V2. In a multi-insert trepanning tool, the cutting forces produced by the individual inserts are transferred through the tool body and guide pads before reaching the

machine spindle. An uneven distribution of these forces leads to radial imbalance, localised stress concentration, excessive deformation, and unstable cutting.

The resultant radial force acting on the tool can be expressed as in Equation (1).

$$F_R = \sqrt{F_x^2 + F_y^2} \quad (1)$$

where F_x and F_y are the lateral force components generated during machining. Lower values and smaller variations of F_R indicate better force balancing and greater dynamic stability. The insert arrangement in Tool V1 created non-uniform load-transfer paths, causing larger force oscillations and localised stress concentration near the insert pockets. By optimising the insert placement and increasing the local structural rigidity, Tool V2 distributed the cutting loads more evenly, reducing the stress-concentration factor, suppressing the force fluctuations, and increasing the structural rigidity. Consequently, Tool V2 showed lower deformation and lower equivalent stress than Tool V1. These results show that the force distribution strongly affects the structural performance of large-diameter trepanning tools.

3.5.2 Industrial scalability and practical implications

The proposed simulation-driven design procedure is largely independent of the specific tool dimensions and can be applied to a range of large-diameter machining problems, including different hole diameters, insert arrangements, and difficult-to-cut materials such as titanium alloys, stainless steels, nickel superalloys, and structural steels. Combining transient force prediction, experimental force validation, and structural analysis allows the performance of a tool to be assessed before it is manufactured, which reduces development cost, limits shop-floor trials, and shortens tool qualification. The approach is particularly relevant to the large-diameter deep holes required in nuclear, aerospace, power-generation, petrochemical, and pressure-vessel components, which is the target application of the validated methodology.

4. CONCLUSIONS

An integrated experimental–numerical approach was used to study the effect of trepanning-tool geometry on cutting performance and structural response for a large-diameter annular cut in SS304L. Two BTA-based configurations were studied by combining finite-element force simulation with experimental force validation on a purpose-built rig. The main findings are as follows:

- A stable machining condition — spindle speed 375 rpm, feed rate 45 mm/min, coolant flow rate 210 LPM — was established from preliminary trials and adopted for the force analysis.
- The finite-element force model was validated experimentally: the predicted and measured steady-state cutting forces agreed to within about 9% for Tool V2 and about 20% for Tool V1, confirming that Tool V2 provides more stable and predictable forces.
- Owing to the improved load balancing and revised insert arrangement, Tool V2 showed a smoother force evolution and reduced force fluctuation.
- The structural analysis showed that Tool V2 had about 44% lower deformation and about 69% lower equivalent stress than Tool V1. Although the absolute values are small for both tools, the relative improvement indicates a stiffer structure and a better-balanced load path.

Overall, the study demonstrates the value of combining simulation-driven design with experimental force validation for developing trepanning tools for hard-to-machine materials. The framework reduces reliance on trial-and-error and provides a general methodology for the design of large-diameter tools intended for deep-hole service.

Statements & Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Availability of Data and Materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Author Contributions

Vinayak M. Kannao: conceptualisation and planning; fabrication of the tools and the purpose-built attachment; and execution of the experimental trials and cutting-force measurements, carried out at the Nuclear Fuel Complex, Hyderabad. Pranav N. Ughade: tool design and CAD modelling; and finite-element simulation. Gangadharudu Talla: overall supervision; analysis of results; writing of the original draft; and review and editing. All authors read and approved the final manuscript.

REFERENCES

1. Dak G, Pandey C (2022) Study on effect of weld groove geometry on mechanical behavior and residual stresses variation in dissimilar welds of P92/SS304L steel for USC boilers. Archives of Civil and Mechanical Engineering 22:140.
<https://doi.org/10.1007/s43452-022-00468-8>
2. Taraphdar PK, Mahapatra MM, Pradhan AK, Singh PK, Sharma K, Kumar S (2020) Evaluation of through-thickness residual stresses in conventional and narrow grooved stainless steel welds. Proceedings of the Institution of Mechanical Engineers, Part L:

Journal of Materials: Design and Applications 234:1165–1179.

<https://doi.org/10.1177/1464420720930355>

3. Acharya S, Moitra A, Bysakh S, Nanibabu M, Krishanan SA, Mukhopadhyay CK, Rajkumar KV, Sasikala G, Mukhopadhyay A, Mondal DK, Ghosh KS, Jha BB, Muraleedharan K (2019) Effect of high strain rate deformation on the properties of SS304L and SS316LN alloys. *Mechanics of Materials* 136:103073.
<https://doi.org/10.1016/j.mechmat.2019.103073>
4. Dak G, Khanna N, Pandey C (2022) Study on narrow gap welding of martensitic grade P92 and austenitic grade AISI 304L SS steel for ultra-supercritical power plant application. *Archives of Civil and Mechanical Engineering* 23:14.
<https://doi.org/10.1007/s43452-022-00540-3>
5. Ahmed A, Lew MT, Diwakar P, Kumar AS, Rahman M (2019) A novel approach in high performance deep hole drilling of Inconel 718. *Precision Engineering* 56:432–437.
<https://doi.org/10.1016/j.precisioneng.2019.01.012>
6. Qayyum F, Shah M, Muqeet A, Afzal J (2016) The effect of anisotropy on the intermediate and final form in deep drawing of SS304L, with high draw ratios: Experimentation and numerical simulation. *IOP Conf Ser Mater Sci Eng* 146:012031.
<https://doi.org/10.1088/1757-899X/146/1/012031>
7. Sun J, Sun C, Yan Z, et al (2025) State-of-art, challenges, and outlook on deep hole boring: chatter suppression, tool wear monitoring, and error measurement. *The International Journal of Advanced Manufacturing Technology* 136:2075–2105.
<https://doi.org/10.1007/s00170-025-15007-x>
8. Chin J-H, Lee L-W (1995) A study on the tool eigenproperties of a BTA deep hole drill—theory and experiments. *Int J Mach Tools Manuf* 35:29–49. [https://doi.org/10.1016/0890-6955\(95\)80007-7](https://doi.org/10.1016/0890-6955(95)80007-7)

9. Chandar JB, Nagarajan L, Kumar MS (2021) Recent research progress in deep-hole drilling process: a review. *Surface Review and Letters* 28:2130003.
<https://doi.org/10.1142/S0218625X21300033>
10. Li X, Zheng J, Yu B, Du Y, Zhou Y (2022) Analytical Model of Hole Diameter and Self-Guiding Machining Mechanism of BTA Deep Hole Drilling. *Materials* 15:5329.
<https://doi.org/10.3390/ma15155329>
11. Thil J, Haddag B, Nouari M, et al (2013) Experimental and analytical analyses of the cutting process in the deep hole drilling with BTA (Boring Trepanning Association) system. *Mechanics & Industry* 14:413–429. <https://doi.org/10.1051/meca/2013087>
12. Liu X, Feng Y (2019) FEA of BTA Deep Hole Drilling Based on ANSYS. *IOP Conf Ser Mater Sci Eng* 611:012021. <https://doi.org/10.1088/1757-899X/611/1/012021>
13. Yang S, Tong X, Ma X, Ji W, Liu X, Zhang Y (2018) The guide block structure design of boring and trepanning association (BTA) deep hole drilling. *The International Journal of Advanced Manufacturing Technology* 99:911–918. <https://doi.org/10.1007/s00170-018-2418-7>
14. Han X, Xie F, Qiu L, Ma H (2025) Multiobjective optimization of chip removal performance of cutting fluid in large diameter titanium alloy deep hole trepanning. *Proc Inst Mech Eng B J Eng Manuf.* <https://doi.org/10.1177/09544054241310340>
15. Gaikwad SV, Mulik RS (2024) Design and development of a trepanning tool for stainless steel using simulation approach. *International Journal on Interactive Design and Manufacturing (IJIDeM)* 18:2143–2150. <https://doi.org/10.1007/s12008-022-00979-x>
16. Rahman HA, Ghani JA, Rasani MRM, et al (2025) Application of finite element analysis and computational fluid dynamics in machining AISI 4340 steel. *Tribol Int* 207:110616.
<https://doi.org/10.1016/j.triboint.2025.110616>

17. Wakchaure MB, Misra M, Menezes PL (2025) Finite Element Simulation of the Laser Shock Peening Process on 304L Stainless Steel. *Materials* 18:2958.
<https://doi.org/10.3390/ma18132958>
18. Prabhu PR, Kulkarni SM, Sharma S (2020) Multi-response optimization of the turn-assisted deep cold rolling process parameters for enhanced surface characteristics and residual stress of AISI 4140 steel shafts. *Journal of Materials Research and Technology* 9:11402–11423. <https://doi.org/10.1016/j.jmrt.2020.08.025>
19. Mia M, Anwar S, Yang X (2025) Finite element modeling of machining with interactive friction model based evolutionary friction. *J Manuf Process* 148:61–74.
<https://doi.org/10.1016/j.jmapro.2025.04.073>
20. Singh A, Gani A (2025) Analysis of stress behavior of drill tool by using ANSYS-2020 R2. *Life Cycle Reliability and Safety Engineering* 14:105–115.
<https://doi.org/10.1007/s41872-024-00286-2>
21. Pelikán L, Slaný M, Stránský O, et al (2023) Novel drill geometries for dry drilling of stainless steel. *J Manuf Process* 92:500–520.
<https://doi.org/10.1016/j.jmapro.2023.03.006>
22. Mathew J, Ramakrishnan N, Naik NK (1999) Investigations into the effect of geometry of a trepanning tool on thrust and torque during drilling of GFRP composites. *J Mater Process Technol* 91:1–11. [https://doi.org/10.1016/S0924-0136\(98\)00416-6](https://doi.org/10.1016/S0924-0136(98)00416-6)
23. Yalçın B, Bolat Ç, Ergene B, Karakılınç U, Yavaş Ç, Öz Y, Ercetin A, Maraş S, Der O (2024) Effect of Drilling Parameters and Tool Diameter on Delamination and Thrust Force in the Drilling of High-Performance Glass/Epoxy Composites for Aerospace Structures with a New Design Drill. *Polymers (Basel)* 16:3011.
<https://doi.org/10.3390/polym16213011>

24. Chen X, Wang Q, An Q, et al (2024) Research on drilling performance and tool life improvement methods of titanium alloy ultra-high-speed drilling bits. The International Journal of Advanced Manufacturing Technology 133:417–431.
<https://doi.org/10.1007/s00170-024-13756-9>
25. Sivaramakrishnaiah M, Reddy RM, Reddy AD, Paramasivam P, Kanti PK, Ayanie AG (2025) Experimental and thermomechanical SPH and FEA model simulation using inconel 825 with tungsten carbide tool. Sci Rep 15:10053.
<https://doi.org/10.1038/s41598-025-95018-6>