



Article History:

Received:
04 April 2026

Accepted:
27 June 2026

Published:
02 July 2026

Effect of Raster Orientation on the Mechanical Response of FDM-Printed PLA, PETG, and PA/Nylon: Tensile Characterization, ANSYS Calibration, and Preliminary Wing-Flow Screening

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تأثير اتجاه مسارات الطباعة على الاستجابة الميكانيكية لمواد PLA و PETG و PA/النايلون المصنعة بتقنية FDM: توصيف خواص الشد، ومعايرة نموذج ANSYS، والتقييم الأولي لتدفق الهواء حول الجناح

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Abstract:

Fused deposition modeling (FDM), a material-extrusion additive-manufacturing process, produces polymer components whose mechanical response depends on deposited-road architecture, inter-road and interlayer bonding, polymer chemistry, thermal history, voids, environmental conditioning, and measurement definitions. This study develops a traceable experimental-computational workflow that couples ASTM D638 Type I tensile characterization of PLA, PETG, and PA/Nylon printed with 0/90° and ±45° raster configurations to ANSYS multilinear isotropic-hardening calibration and a preliminary force-level screening of a lattice-integrated aircraft-wing prototype. The ±45° configuration increased mean ultimate tensile strength (UTS) from 21.63 ± 6.63 to 52.92 ± 3.10 MPa for PLA (+144.7%), from 22.62 ± 2.83 to 38.93 ± 1.02 MPa for PETG (+72.1%), and from 19.96 ± 1.96 to 41.36 ± 1.59 MPa for PA/Nylon (+107.2%). Young's modulus increased for PLA (+61.7%) and PETG (+9.4%) but decreased for PA/Nylon (-25.5%), while the recorded displacement at break and the software-defined ACurva metric increased in all three material families. For the ANSYS calibration, PLA2 and PETG2 showed close paired-row agreement (MAPE 1.33%, R² = 0.9994 and MAPE 1.51%, R² = 0.9992, respectively). PA2 showed weaker partial-range agreement (MAPE 12.58%, R² = 0.6415), although the peak of the complete prepared PA2 curve differed from the experimental mean by only -4.49%. In the wing-flow screening, Lattice drag magnitude exceeded Solid drag in all nine workbook-labeled material-velocity cases; lift increased in eight cases and decreased by 30.17% for the PLA-labeled case at 25 m/s. The principal contribution is a reproducible, scope-controlled bridge from specimen-level tensile records to constitutive input and preliminary component force comparison, with explicit boundaries for subsequent structural, manufacturing, and physical validation.

Keywords: fused deposition modeling; raster orientation; PLA; PETG; polyamide; ASTM D638; tensile testing; ANSYS; multilinear isotropic hardening; lattice structure.

المخلص

تُعد نمذجة الترسيب المنصهر (FDM) إحدى عمليات التصنيع بالإضافة القائمة على بثق المواد، وتنتج مكونات بوليمرية تتأثر استجاباتها الميكانيكية ببنية مسارات الترسيب، والترابط بين المسارات وبين الطبقات، والتركيب الكيميائي للبوليمر، والتاريخ الحراري، والفراغات الداخلية، وظروف التهئية البيئية، إضافةً إلى تعريفات القياس المستخدمة. تطور هذه الدراسة منهجية تجريبية-حسابية قابلة للتتبع، تربط بين توصيف خواص الشد لعينات من النوع الأول وفق معيار ASTM D638، والمصنعة من مواد PLA و PETG و PA/النايلون باتجاهي مسارات طباعة 0/90° و ±45°، وبين معايرة نموذج التصلد المتناحي متعدد الخطوط في برنامج ANSYS، وصولاً إلى فحص أولي على مستوى القوى لنموذج أولي لجناح طائرة مدمج به هيكل شبكي.

أدى استخدام التكوينين ±45° إلى زيادة متوسط مقاومة الشد القصوى (UTS) من 6.63 ± 21.63 إلى 3.10 ± 52.92 ميغا باسكال لمادة PLA، بزيادة قدرها 144.7%، ومن 2.83 ± 22.62 إلى 1.02 ± 38.93 ميغا باسكال لمادة PETG، بزيادة قدرها 72.1%، ومن 1.96 ± 19.96 إلى 1.59 ± 41.36 ميغا باسكال لمادة PA/النايلون، بزيادة قدرها 107.2%. كما ارتفع معامل يونغ لمادتي PLA و PETG بنسبة 61.7% و 9.4% على التوالي، في حين انخفض لمادة PA/النايلون بنسبة 25.5%. وفي الوقت نفسه، ازدادت قيم الإزاحة المسجلة عند الكسر ومؤشر ACurva المعرف بواسطة برنامج الاختبار في عائلات المواد الثلاث جميعها.

وفي معايرة ANSYS، أظهرت حالتا PLA2 و PETG2 توافقاً وثيقاً بين الصفوف المتناظرة، حيث بلغت قيمة متوسط الخطأ المطلق النسبي 1.33% (MAPE) ومعامل التحديد $R^2 = 0.9994$ لمادة PLA2 و $R^2 = 0.9992$ لمادة PETG2. أما حالة PA2 فأظهرت توافقاً أضعف ضمن النطاق الجزئي للمقارنة، بقيمة MAPE بلغت 12.58% ومعامل تحديد $R^2 = 0.6415$ ، رغم أن قمة المنحنى الكامل المعد لمادة PA2 اختلفت عن المتوسط التجريبي بنسبة لم تتجاوز 4.49%. وفي الفحص الأولي لتدفق الهواء حول الجناح، كانت قيمة قوة السحب في التكوين الشبكي Lattice أعلى من نظيرتها في التكوين المصمت Solid في جميع حالات المادة-السرعة التسرع المسجلة في ملف العمل. كما ازدادت قوة الرفع في ثماني حالات، بينما انخفضت بنسبة 30.17% في الحالة الموسومة بـ PLA عند سرعة 25 م/ث.

وتتمثل المساهمة الرئيسية لهذه الدراسة في إنشاء مسار مترابط، قابل لإعادة التطبيق ومضبوط النطاق، يبدأ من سجلات اختبارات الشد على مستوى العينات، ويمتد إلى إعداد المدخلات الدستورية للمواد، ثم إلى المقارنة الأولية للقوى على مستوى المكون، مع تحديد واضح لحدود الدراسة ومتطلبات التحقق اللاحق على المستويات الإنشائية والتصنيعية والفيزيائية.

الكلمات المفتاحية: نمذجة الترسيب المنصهر؛ اتجاه مسارات الطباعة؛ PLA؛ PETG؛ البولي أميد؛ ASTM D638؛ اختبار الشد؛ ANSYS؛ التصلد المتناحي متعدد الخطوط؛ الهيكل الشبكي.

1. Introduction

Material-extrusion additive manufacturing builds polymer parts through successive deposition of thermoplastic roads rather than by forming a homogeneous polymer block. The resulting response is directionally conditioned by road alignment, inter-road and interlayer bonding, voids, thermal history, process parameters, and loading direction [1-4]. Raster orientation is therefore an important design variable because it changes the relationship between deposited roads and the tensile axis without necessarily changing the external specimen geometry.

Previous studies have demonstrated orientation-dependent tensile behavior in FDM/FFF polymers, including PLA, PETG, PA-based materials, and other thermoplastics [5-11]. However, direct numerical comparison across studies is complicated by differences in filament grade, printer and process window, infill, raster definition, specimen conditioning, test method, and data-reduction basis. A further practical challenge is the transparent transfer of measured coupon response into finite-element material inputs while preserving the distinction between measured properties, derived quantities, and modelling assumptions.

A remaining integration gap is the transparent connection of orientation-dependent coupon data, specimen-level variability, constitutive calibration, and component-level screening within one traceable workflow. The present study addresses that integration problem rather than claiming a universal optimum raster angle: original group identifiers and record discrepancies are preserved, modelling inputs are distinguished from measured quantities, and the wing analysis is explicitly limited to the force-level evidence available.

Accordingly, the objectives are to (i) quantify the material-specific effect of changing the raster configuration from 0/90° to ±45° for PLA, PETG, and PA/Nylon; (ii) document specimen-level variability and data-quality controls; (iii) establish traceable ANSYS constitutive inputs for the selected ±45° groups; and (iv) connect those inputs to a preliminary Solid/Lattice wing-flow force screening without extending the conclusions beyond the available experimental and computational evidence.

2. Materials and Methods

2.1 Experimental design and specimen records

The six study groups were retained as PLA1, PLA2, PETG1, PETG2, PA1, and PA2; suffix 1 denotes the 0/90° raster configuration and suffix 2 denotes ±45°. The project records identify 34 planned specimen positions, whereas the six tensile-test PDF summaries contain 33 specimen rows and the raw text files contain 32 visible specimen blocks. The PA1 discrepancy (six PDF rows but five visible raw blocks) was documented rather than reconstructed. The specimens followed nominal ASTM D638 Type I geometry: 165 mm overall length, 19 mm

grip-section width, 13 mm narrow-section width, 3.2 mm thickness, 57 mm gauge length, and 76 mm fillet radius [12], giving a nominal narrow-section area of 41.6 mm². The retained nominal printing configuration used a 0.4 mm nozzle, 0.2 mm layer height, 100% infill, rectilinear infill, and 16 layers across the nominal thickness. Printer model, filament grade, thermal settings, printing speed, and build-environment fields that were absent from the retained records were not inferred.

Table 1. Experimental group dictionary and row allocation.

Group	Polymer	Raster configuration	n (PDF rows)
PLA1	PLA	0/90°	6
PLA2	PLA	±45°	5
PETG1	PETG	0/90°	6
PETG2	PETG	±45°	5
PA1	PA/Nylon	0/90°	6
PA2	PA/Nylon	±45°	5

Note. Group statistics use the PDF specimen-summary rows shown here. The 34 planned positions, 33 PDF rows, and 32 visible raw blocks are retained as separate reproducibility counts and are not forced into artificial agreement.

2.2 Experimental and computational documentation

Representative study images document the computational tensile-coupon response, the aircraft-wing CAD geometry, and the preliminary flow field. These images are traceability records for the experimental-computational workflow and are not treated as additional measurements.

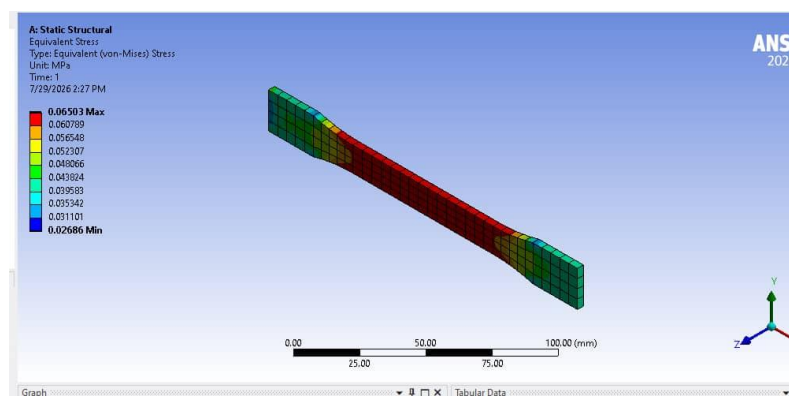


Figure 1. Representative ANSYS tensile-coupon contour retained from the computational record.

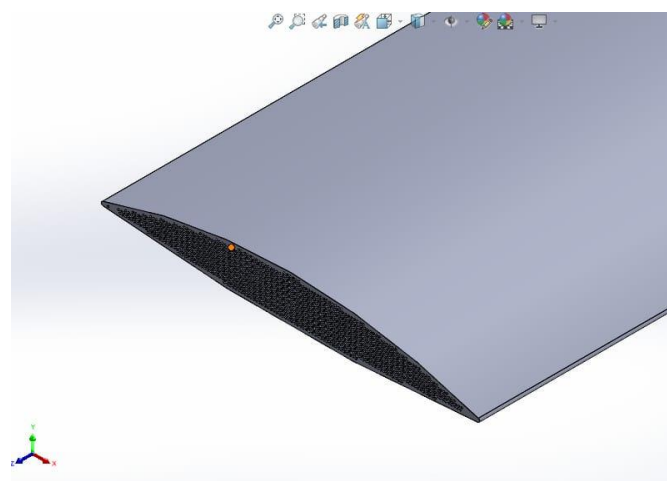


Figure 2. Representative CAD view of the aircraft-wing prototype with lattice-like internal region.

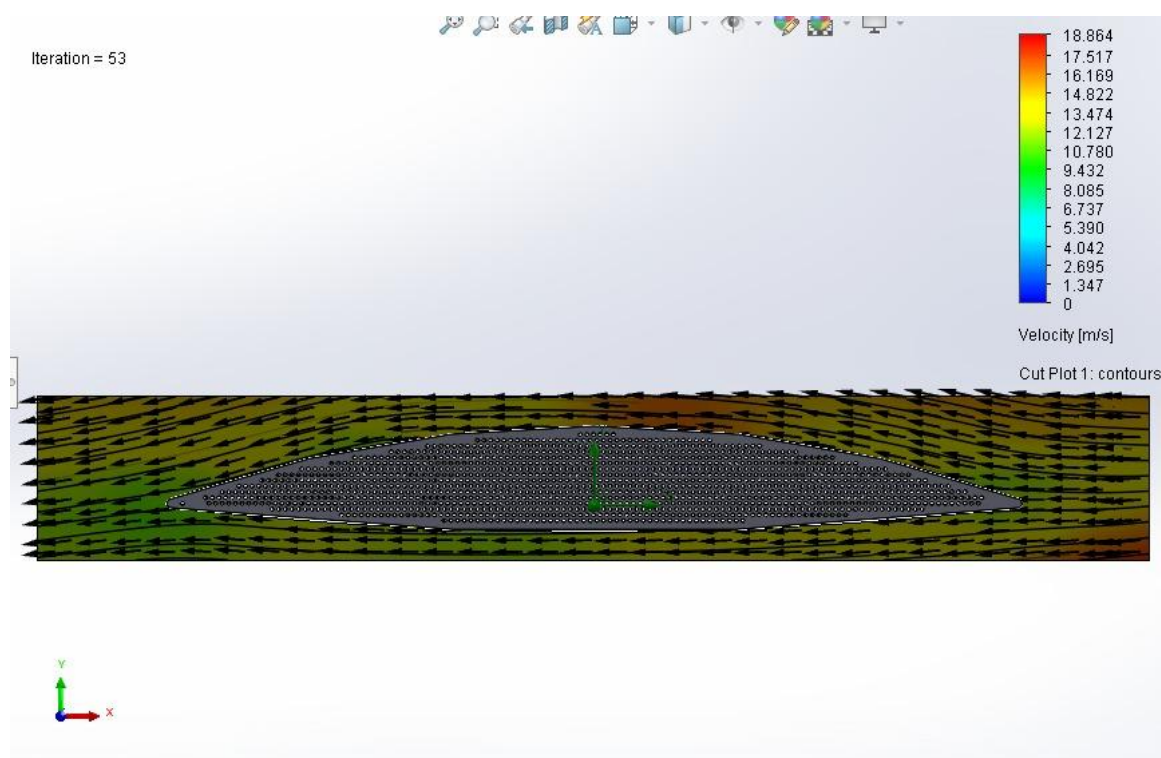


Figure 3. Representative ANSYS flow-field visualization used in the preliminary wing-flow screening.

2.3 Metrics and data treatment

The tensile PDF summaries report MaxF, MaxL, Def.Brk, Def_MaxF, TenMod, ACurva, BrkF, YoungM, and Section. MaxL is treated as the reported maximum-stress/UTS field because it is expressed in MPa; YoungM and TenMod are retained as distinct software fields unless equivalence is explicitly demonstrated. Group means, sample standard deviations (n-1 denominator), medians, ranges, and coefficients of variation ($CV = 100 \times \text{sample SD} / \text{group mean}$) were calculated from specimen-level values. Orientation-related percentage change was calculated as $100 \times (\pm 45^\circ \text{ mean} - 0/90^\circ \text{ mean}) / 0/90^\circ \text{ mean}$ using full-precision source values. PLA1 Specimen 5, documented in the project record as a low-strength printing-defect outlier, was retained in the primary statistics rather than removed post hoc. Because the group sizes were only five or six and the assumptions required for formal inferential tests were not established, the orientation comparisons are reported descriptively. ACurva is retained as a software-defined force-displacement area metric in N·mm and is not relabelled as fracture toughness. Def.Brk is reported in millimetres because the retained records do not establish whether displacement was based on crosshead travel or extensometry.

2.4 ANSYS material calibration and wing-flow screening

The $\pm 45^\circ$ group means for PLA2, PETG2, and PA2 were selected as the constitutive-input cases because each recorded a higher mean UTS than its paired 0/90° group in the present dataset; this selection is study-specific and is not presented as a universal optimal orientation. Isotropic-elastic plus multilinear isotropic-hardening material inputs were constructed in ANSYS Mechanical. Young's modulus was taken from the corresponding group mean; Poisson's ratios of 0.36 for PLA and 0.40 for PETG and PA/Nylon were treated as literature-based modelling inputs rather than project-measured properties. Plastic strain was prepared as $\epsilon_p = \epsilon - \sigma/E$, with the first plastic-strain row fixed at zero to satisfy the ANSYS multilinear-hardening convention [13,14]. Model-to-input agreement was summarized using MAPE, MAE, RMSE, and diagnostic R^2 on the available paired rows, while the complete prepared-curve peak was reported separately so that partial-range PA2 diagnostics were not conflated with the full material curve. This comparison is a material-calibration check, not mesh-independent structural validation. The wing-flow workbook contains 36 matched force entries (three workbook-labeled material cases $\times$ three velocities $\times$ two configurations $\times$ two force types) for Solid/Sold and Lattice/Latec at 15, 20, and 25 m/s. Drag is reported by magnitude for the present comparison. A force-based lift-to-drag ratio was derived separately for each configuration as $|L|/|D|$; Solid and Lattice forces were not summed for this ratio. The material names in the CFD workbook are treated as case labels; the retained record does not by itself establish polymer chemistry as an independent aerodynamic causal variable. The wing analysis is therefore limited to comparative force screening and is not treated as complete CFD, structural, or physical validation.

3. Results

3.1 Tensile response

Table 2. Group-level tensile property summary.

Group	UTS (MPa)	YoungM (MPa)	Def.Brk (mm)	ACurva (N·mm)
PLA1	21.63 ± 6.63	799.46 ± 192.09	2.66 ± 0.30	1,159.14 ± 413.70
PLA2	52.92 ± 3.10	1292.71 ± 57.58	6.75 ± 0.53	9,740.37 ± 1,550.47
PETG1	22.62 ± 2.83	700.25 ± 28.42	3.12 ± 0.41	1,455.63 ± 419.29
PETG2	38.93 ± 1.02	766.14 ± 6.19	8.44 ± 0.63	9,640.06 ± 1,114.87
PA1	19.96 ± 1.96	223.75 ± 37.54	27.43 ± 1.82	18,244.78 ± 1,241.01
PA2	41.36 ± 1.59	166.60 ± 20.10	301.87 ± 17.73	407,691.12 ± 31,735.22

Within each polymer family, the $\pm 45^\circ$ group has a higher mean UTS than its 0/90° counterpart. PLA2 records the highest mean UTS and YoungM among the six groups, whereas PA2 records the largest Def.Brk and ACurva values.

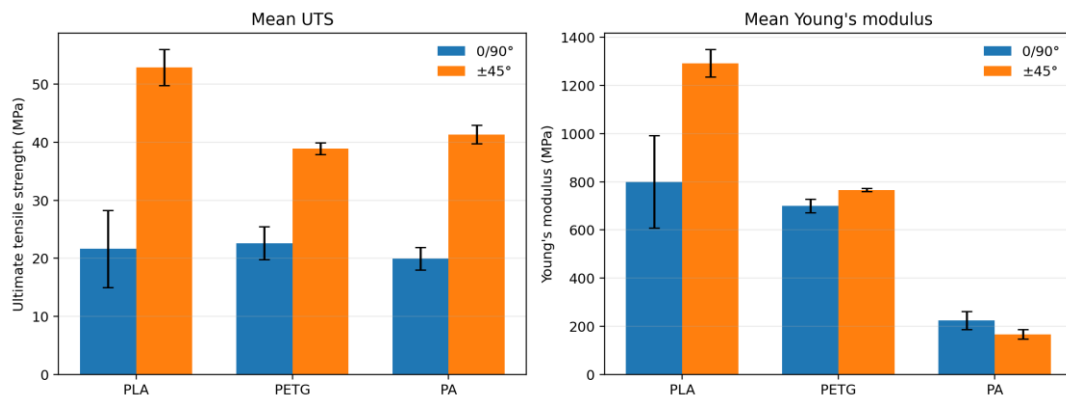


Figure 4. Mean UTS and Young's modulus by polymer and raster configuration. Error bars show sample standard deviation.

3.2 Orientation-related changes and variability

Table 3. Relative change from 0/90° to $\pm 45^\circ$ by material family.

Polymer	Δ UTS (%)	Δ YoungM (%)	Δ Def.Brk (%)	Δ ACurva (%)
PLA	+144.7	+61.7	+153.99	+740.3
PETG	+72.1	+9.4	+170.16	+562.3
PA/Nylon	+107.2	-25.5	+1000.37	+2134.6

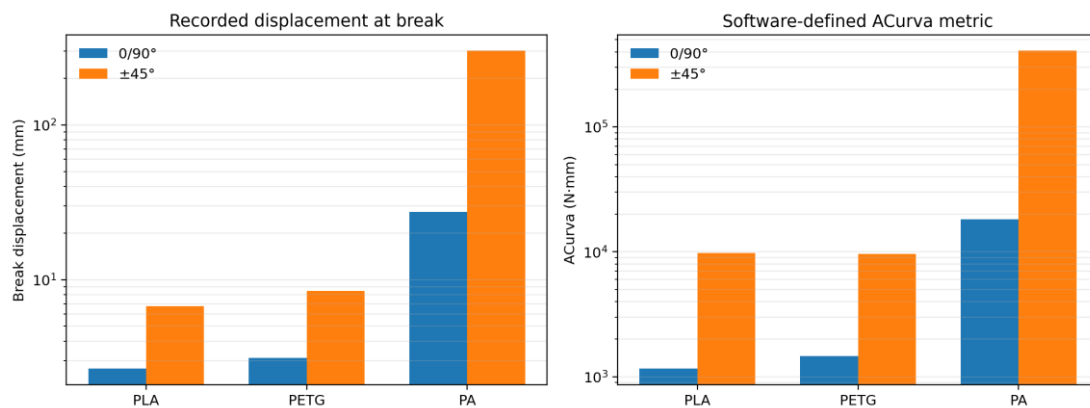
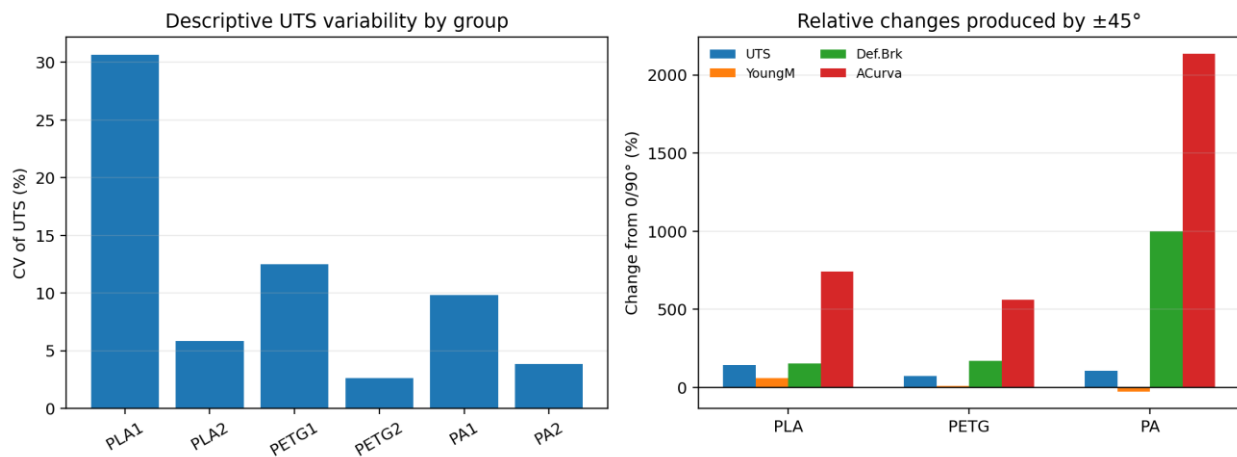


Figure 5. Recorded displacement at break and ACurva on logarithmic scales. ACurva is a software-defined N·mm metric.

Table 4. Specimen-level distribution support.

Group	UTS median (MPa)	UTS range (MPa)	YoungM median (MPa)	YoungM range (MPa)	Def.Brk median (mm)	UTS CV (%)
PLA1	24.04	8.53–26.33	865.32	414.71–929.98	2.72	30.66
PLA2	52.18	50.35–58.11	1309.77	1209.66–1364.01	6.7	5.86
PETG1	22.88	19.44–27.00	701.48	656.05–733.17	3.05	12.49
PETG2	38.69	37.69–40.07	770.1	758.49–770.96	8.48	2.61
PA1	19.43	18.15–23.77	208.99	201.22–298.77	27.92	9.83
PA2	40.42	39.89–43.40	160.02	148.58–200.82	302.31	3.84

The specimen-level statistics reinforce the mean comparison. PLA1 has the widest UTS spread and the highest UTS CV (30.66%), reflecting the retained low-strength Specimen 5. PETG2 has the lowest UTS CV (2.61%), while PA2 combines a low UTS CV (3.84%) with greater modulus variability than PETG2. Importantly, the UTS CV is lower for every $\pm 45^\circ$ group than for its paired $0/90^\circ$ group (PLA: 5.86% vs 30.66%; PETG: 2.61% vs 12.49%; PA/Nylon: 3.84% vs 9.83%); this remains a descriptive consistency observation rather than an inferential orientation effect.

**Figure 6.** Descriptive UTS variability and orientation-induced relative changes. The comparisons are descriptive; no inferential significance is implied.

3.3 ANSYS calibration results

Table 5. ANSYS material-calibration and verification summary.

Case	E (MPa)	ν	Full-curve peak (MPa)	Experimental UTS (MPa)	Difference (%)	Paired rows	MAPE (%)	R ²
PLA2	1,292.71	0.36	52.814	52.916	-0.19	19	1.33	0.9994
PETG2	766.14	0.40	38.733	38.934	-0.52	20	1.51	0.9992
PA2	166.60	0.40	39.503	41.360	-4.49	13 (partial)	12.58	0.6415

Note. The PA2 paired-row statistics refer to a partial workbook range and are not the peak of the complete prepared PA2 constitutive curve.

PLA2 and PETG2 show close peak-level and paired-row correspondence. PA2 requires separate interpretation: the complete prepared curve peaks at 39.503 MPa, only 4.49% below the experimental mean of 41.360 MPa, whereas the exposed partial paired range shows materially larger row-wise error.

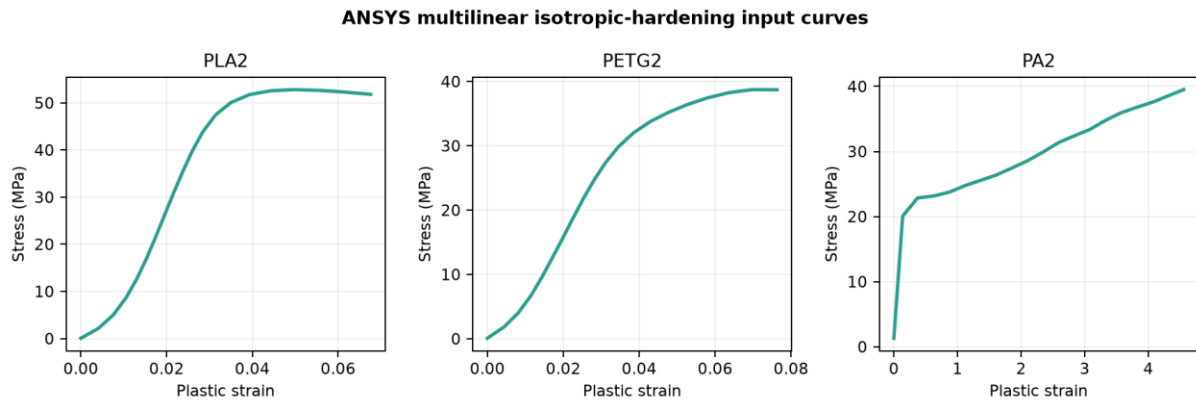


Figure 7. Multilinear isotropic-hardening curves used as ANSYS material inputs.

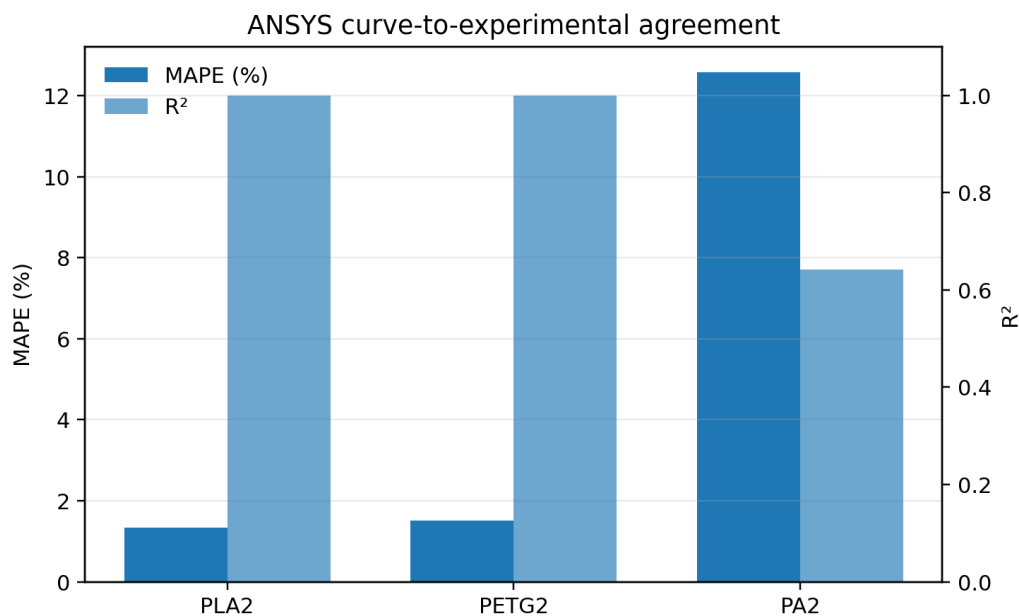


Figure 8. ANSYS curve-to-input agreement metrics. PA2 refers to the partial paired-range diagnostic; the complete PA2 curve is assessed separately by its full-curve peak.

3.4 Preliminary wing-flow screening

Table 6. Preliminary force comparison from the wing-flow workbook.

Material	Speed (m/s)	Solid drag (N)	Lattice drag (N)	Δ drag (%)	Solid lift (N)	Lattice lift (N)	Δ lift (%)
PLA	15	1.908	4.302	+125.42	5.356	6.224	+16.21
PLA	20	3.204	7.567	+136.16	8.770	10.602	+20.88
PLA	25	5.231	11.448	+118.84	22.314	15.581	-30.17
PETG	15	2.684	4.288	+59.78	5.149	6.073	+17.96
PETG	20	4.663	7.559	+62.10	9.305	10.795	+16.02
PETG	25	7.108	11.447	+61.05	14.252	15.420	+8.19
PA	15	2.694	4.292	+59.30	5.161	6.256	+21.22
PA	20	4.633	7.569	+63.39	9.375	10.473	+11.71
PA	25	7.228	11.469	+58.68	14.015	16.106	+14.92

Note. Displayed forces are rounded to three decimals; percentage changes were calculated from the full-precision workbook values. Material names are workbook case labels. Drag values are presented by magnitude for the comparative screening.

Across the nine matched cases, the Lattice configuration increased drag magnitude by approximately 59-136%. Lift increased for PETG and PA/Nylon at all three velocities and for PLA at 15 and 20 m/s; the only negative Lattice-relative lift change was PLA at 25 m/s (-30.17%). The separately calculated force-based $|L|/|D|$ ratio was higher for the Solid configuration in all nine cases, indicating a consistent drag-efficiency penalty for the recorded Lattice cases within this force-screening dataset.

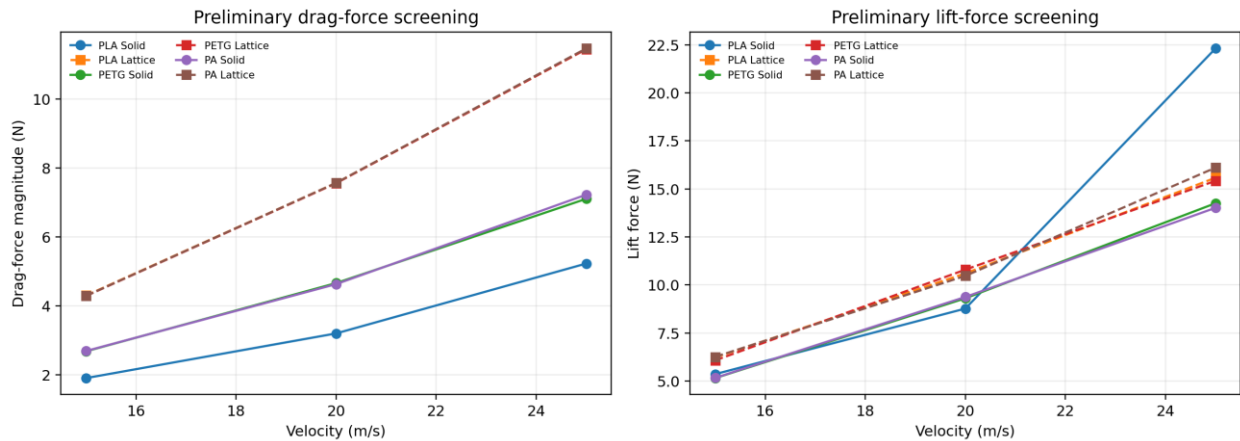


Figure 9. Preliminary Solid-Lattice drag- and lift-force screening at 15, 20, and 25 m/s using workbook force records.

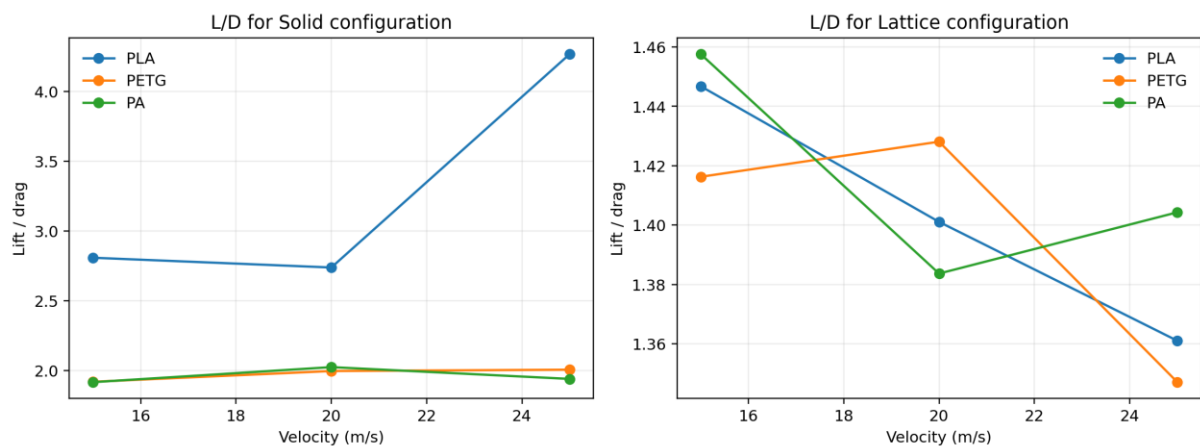


Figure 10. Force-based lift-to-drag ratio ($|L|/|D|$) calculated separately for Solid and Lattice configurations from the workbook force records; Solid and Lattice forces are not summed.

4. Discussion

The results show that raster configuration was a first-order variable within the retained dataset. Mean UTS increased for every polymer family when the raster configuration changed from 0/90° to $\pm 45^\circ$, but the complete response profile was material-specific. PLA combined the largest relative UTS increase with a strong YoungM increase; PETG showed a smaller stiffness change with a substantial increase in recorded displacement; and PA/Nylon combined higher UTS with lower YoungM and exceptionally large Def.Brk and ACurva values. A plausible architecture-level interpretation is that the $\pm 45^\circ$ roads create a more distributed, shear-sensitive load path in which rotated roads can deform or reorient before final failure—a "scissor-like" interpretation retained here as a conceptual mechanism rather than a microscopically demonstrated failure mode. These findings support a multi-objective interpretation of strength, stiffness, deformation, and the software-defined area metric rather than a single ranking based only on UTS.

The comparison with previous FDM studies is best interpreted at the mechanism and trend level. Reviews and material-specific studies consistently show that raster orientation, build/process parameters, interfacial bonding,

and conditioning can materially alter FDM mechanical response [1,3,4,6-11,15]. Studies of PLA and PETG likewise demonstrate that the preferred raster angle depends on material, process window, and targeted property [6-11]. The direction and magnitude observed here therefore need not match a universal ranking: the present PLA and PETG results confirm strong orientation sensitivity, while the different Young's Modulus responses across PLA, PETG, and PA/Nylon reinforce that no single orientation factor should be transferred across polymers. For PA/Nylon, moisture and conditioning are especially important contextual variables [10,15]; because the retained records do not establish drying, storage, humidity, or the exact displacement-measurement basis, the unusually large PA2 deformation is reported as recorded rather than generalized as an intrinsic material constant.

The ANSYS results support the usefulness of the group-average $\pm 45^\circ$ curves as coupon-scale constitutive inputs for PLA2 and PETG2, where both peak-level and paired-row agreement are close. This conclusion remains model-scope specific: multilinear isotropic hardening does not, by itself, reproduce road-scale anisotropy, inter-road debonding, rate dependence, moisture evolution, progressive damage, or fracture [1,13-15]. PA2 is therefore interpreted as a focused calibration-refinement case rather than as evidence that the entire modelling framework fails. The priority next step is to export the complete PA2 numerical force-displacement and stress-strain histories on definitions identical to the experiment, reconcile area and gauge/displacement conventions, and confirm conditioning and loading rate before introducing a more complex orthotropic, rate-dependent, or damage formulation.

The wing extension is an early design screen. Lattice drag magnitude exceeded Solid drag in all nine workbook-labeled material-velocity cases, lift increased in eight cases, and the derived $|L|/|D|$ ratio favored Solid in every case. These results identify Solid as the lower-drag reference for the recorded force matrix; they do not demonstrate that a lattice configuration is inferior for all design objectives. Lattice performance depends on topology, relative density, cell size, member dimensions, process fidelity, and the structural comparison basis [16-19]. Mass, structural stiffness, failure resistance, manufacturability, and internal-flow/architecture objectives were not jointly evaluated here. In addition, because the retained CFD record does not establish a fluid-structure coupling mechanism linking polymer properties to geometry or flow, differences among the material-labeled CFD cases are interpreted as recorded simulation-case differences rather than direct evidence of a polymer-chemistry effect on aerodynamics. A defensible component-level extension therefore requires dimensioned geometry, fluid properties, boundary conditions, mesh and convergence documentation, structural load transfer, manufacturing inspection, and physical testing.

From an integrated design perspective, PLA2 is the leading strength-and-stiffness candidate among the tested $\pm 45^\circ$ groups, PETG2 occupies a balanced strength-deformation position, and PA2 is a highly compliant/high-area-response candidate that requires the strongest measurement and conditioning verification. These material roles should guide any future structural wing analysis, while the CFD material labels should remain separate from structural material assignment until a coupled, geometry-specific model is defined.

5. Limitations and reproducibility boundary

Several fields required for fully independent reproduction were not present in the retained experimental record: printer model, filament grade, nozzle and bed temperatures, printing speed, build environment, tensile crosshead/test speed, load-cell capacity, ambient temperature and humidity, specimen conditioning, and displacement-measurement basis. PA/Nylon conditioning remains unresolved, group sizes are small ($n = 5-6$), and the reported orientation percentages are descriptive rather than inferential; no statistical significance should be claimed from these comparisons. The ANSYS Mechanical comparison is a material-input calibration check rather than mesh-independent structural validation; only the available PA2 solved-model mesh/displacement record serves as a direct verification anchor. For the wing-flow analysis, the retained record does not fully document native geometry dimensions, fluid-property conventions, complete boundary conditions, mesh independence, reference area, force-integral definitions, or physical aerodynamic validation. Consequently, the wing results are reported as a preliminary force-level comparison, not as CFD certification, structural certification, mass-reduction proof, manufacturing qualification, or aerodynamic validation.

6. Conclusions

Raster configuration materially changed the tensile response of all three FDM polymer families examined. Relative to $0/90^\circ$, the $\pm 45^\circ$ groups increased mean UTS by 144.7% for PLA, 72.1% for PETG, and 107.2% for PA/Nylon; these are descriptive results for the recorded configurations, not universal orientation factors.

Stiffness and deformation changes were material-specific: Young's Modulus increased for PLA and PETG but decreased for PA/Nylon, while Def.Brk and ACurva increased for all three families. PA2 therefore remains the highest-priority case for confirming displacement definition, conditioning history, and interpretation of the software-defined area metric.

The selected $\pm 45^\circ$ group means provided effective coupon-scale ANSYS inputs for PLA2 and PETG2. PA2 retained close full-curve peak correspondence (-4.49%) but weaker partial-range paired agreement, making

complete definition-matched PA2 export and mesh-controlled verification the priority for the next calibration cycle.

The preliminary wing-flow screening found higher Lattice drag magnitude and lower force-based $|L|/|D|$ than Solid in all nine workbook-labeled cases, while lift response remained case-dependent. These results support force-level configuration screening only and do not constitute structural or aerodynamic qualification of the lattice design.

The principal contribution is the traceable integration of specimen-level tensile evidence, transparent data-quality controls, constitutive calibration, and a scope-limited component force screen. The next defensible step is a geometry-specific structural and CFD qualification workflow with declared material orientation, mesh convergence, manufacturing fidelity, and physical validation.

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