Development and Preliminary Evaluation of a Poka-Yoke Support Hook for Brake Calipers During Brake Pad Replacement

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ABSTRACT

Temporarily supporting a removed brake caliper is a necessary part of brake maintenance because the hydraulic hose must not serve as a suspension element. This study examines the design of a caliper support hook made from AISI 1020 steel and interprets the graphical evidence from a static simulation. An applied case study was conducted, integrating a documentary review, an exploratory literature search guided by PRISMA transparency criteria, failure mode and effects analysis (FMEA), and interpretation of four numerical plots and one material data sheet. The model shown contains two hooks, perforated arms, joints, and a diagonal bar. The plot scales show upper limits of 36.56 MPa for von Mises equivalent stress, 0.1925 mm for resultant displacement, and 1.339×10^{-4} for equivalent strain. The visible distribution concentrates higher stress and strain near the upper-hook transition, while displacement increases toward the loaded lower end. The AISI 1020 data sheet indicates a yield strength of 351.571 MPa, consistent with the displayed minimum factor of safety of approximately 9.6. However, load, contact, and mesh-convergence documentation is missing, so no allowable capacity is established. FMEA ranks unintended disengagement as the highest internal priority, a condition that the structural plot does not verify. The 10.0- and 8.8-minute values represent a projected 12% reduction, not workshop measurements. Improvements to the geometric transition, retention, and joint modeling are proposed, together with a verification plan. No physical prototype exists; drawings remain pending, and an illustrative render is included. The contribution is to connect the available numerical results with design decisions and explicit limits on interpretation.

Keywords: Poka-Yoke; brake caliper; AISI 1020 steel; FMEA; brake pad replacement.

INTRODUCTION

During brake pad replacement in a disc-brake system, the caliper may be temporarily removed to provide access to components. During this interval, it must be adequately supported so that the hydraulic hose does not bear its weight or become twisted or tensioned. HELLA's technical guidance recommends securing the caliper with a suitable support and not leaving it hanging from the hose (HELLA, n.d.).

The academic project arose from the need to reduce improvised practices during this operation. The Cleaner Production report describes possible interruptions, time loss, and risk of damage when a technician searches for or uses non-standard temporary supports (Kamicase Team, n.d.-c). These records support the design problem but do not quantify the actual frequency of damage, leaks, or workshop accidents.

The proposed solution is a reusable hook for temporarily supporting the caliper. The team confirmed that the final selected material is AISI 1020 steel and that a three-dimensional model exists. Earlier documents refer to AISI 1018 and an aluminum version; because these versions are incompatible, neither is treated as a specification of the final design.

The objective of this article is to document the hook's development, review the FMEA, interpret the static simulations and material properties, analyze operational estimates, and guide improvements. Confirmed design

decisions, preventive judgments, numerical results, and time and cost estimates are distinguished. No physical prototype exists, and no physical tests have been conducted.

LITERATURE REVIEW

SALSA Methodology Applied

Search. An exploratory, targeted search was conducted using the sources and technical references already documented in the project file. The search focused on Poka-Yoke systems, error prevention, maintenance support tools, SMED, failure mode and effects analysis (FMEA), AISI 1020 steel, and finite-element simulation. Relevant sources included Shingo (1985, 1986), Vidor and Saurin (2011), Lazarevic et al. (2019), AIAG (2019), HELLA, Autodesk, SOLIDWORKS/Dassault Systèmes, Visser, Packer, and voestalpine High Performance Metals. The search terms documented in the project included “brake caliper hanger,” “Poka-Yoke automotive maintenance,” “caliper support hook simulation,” “mesh convergence,” and “global contact.”

Appraisal. Sources were assessed according to their relevance to the design problem and the type of evidence they provide. Peer-reviewed literature was used to frame Poka-Yoke concepts and their classification; established books were used for the principles of SMED and source inspection; technical manufacturer and software documentation was used for brake-maintenance guidance, material properties, contact definitions, and finite-element interpretation. Internal project documents were treated as records of the team’s design decisions and estimates, not as independent experimental validation. No source was assumed to prove the physical safety or effectiveness of the proposed hook.

Synthesis. The literature was organized into four themes: (1) Poka-Yoke and prevention of operational errors; (2) SMED and preparation of maintenance work; (3) FMEA as a preventive risk-analysis tool; and (4) material selection and verification of finite-element models. These themes connect the literature directly to the design decisions and evidence available for the caliper-support hook.

Analysis. The sources were interpreted in relation to the project’s main questions: whether the hook can reduce improvisation, which failure modes require priority attention, what can legitimately be inferred from the static simulation, and what additional evidence is needed before the device can be considered safe and effective. The search was exploratory rather than systematic: a complete record of retrieved items, duplicates, exclusions, and full-text screening was not available. Accordingly, this section does not claim to be a completed PRISMA systematic review.

Table 1. Literature Review Analysis

#	Author(s) and year	Title / source	Appraisal (quality/relevance)	Synthesis (key findings)	Analysis (relationship to this project)
1	Shingo (1986)	Zero Quality Control: Source Inspection and the Poka-Yoke System	Foundational book; high conceptual relevance	Poka-Yoke aims to prevent errors at the source or make them immediately detectable.	Frames the hook as a preventive aid, while requiring proof that its geometry prevents or reveals misuse.
2	Lazarevic et al. (2019)	A systematic literature review of Poka-Yoke and novel approach to theoretical aspects	Peer-reviewed review; high relevance	Poka-Yoke definitions and classifications can vary; the preventive mechanism must be specified.	Supports describing the device cautiously as Poka-Yoke-oriented rather than claiming that it eliminates all human error.
3	Vidor &	Conceitos e características de sistemas	Peer-reviewed	Poka-Yoke	Highlights the

	Saurin (2011)	poka-yokes: uma revisão de literatura	review; relevant to design and operation	systems should be understood in relation to work processes and operating conditions.	need to assess placement, retention, user behavior, and inspection throughout service life.
4	Shingo (1985)	A Revolution in Manufacturing: The SMED System	Foundational book; high relevance to setup-time reduction	SMED identifies and organizes setup activities to reduce avoidable time.	Provides a framework for testing whether preparing and locating the hook reduces interruptions; current times remain estimates.
5	AIAG (2019)	New AIAG & VDA FMEA Handbook and Trainings Available!	Industry guidance; high methodological relevance	The AIAG–VDA approach uses Action Priority rather than relying solely on the traditional risk priority number (RPN).	Clarifies that project S × O × D scores are internal screening values, not empirical failure rates or official AIAG–VDA Action Priority.
6	HELLA (n.d.)	Changing brake pads, brake discs and brake calipers	Technical maintenance guidance; high practical relevance	A removed brake caliper should be supported appropriately and not left hanging from its hydraulic hose.	Establishes the maintenance need addressed by the hook, but does not validate this specific design.
7	voestalpine High Performance Metals (n.d.)	AISI 1020	Supplier material information; condition-dependent	Steel designation alone does not determine the strength of a finished component; supply condition and geometry matter.	Supports treating AISI 1020 as the selected material input while requiring confirmation of actual condition and properties.
8	Autodesk (n.d.)	Mesh Convergence	Simulation guidance; high technical relevance	Mesh refinement should be compared at consistent locations to assess numerical convergence.	Supports further convergence checks before interpreting the reported stress as a reliable maximum.
9	Dassault Systèmes (2016)	Maximum von Mises Stress Criterion	Finite-element software documentation; high technical	The von Mises criterion compares equivalent	Provides context for the arithmetic consistency of the reported

			relevance	stress with a material yield limit for ductile materials.	safety factor, not independent validation of the model.
10	Packer (n.d.)	SOLIDWORKS Simulation: An Explanation of the Global Contact Option	Software technical article; relevant to model setup	Contact assumptions affect load transfer and the response of connected components.	Supports documenting contact definitions and checking whether idealized joints represent the proposed assembly.
11	Visser (n.d.)	What Is a Stress Singularity in SOLIDWORKS Simulation?	Technical explanation; relevant to result interpretation	Local stress peaks should be assessed through mesh refinement rather than color plots alone.	Supports inspecting the upper-hook transition and determining whether local stress converges.
12	PRISMA Statement (n.d.)	PRISMA 2020 Statement and PRISMA Extension for Scoping Reviews	Reporting guidance; methodological relevance	Transparent reviews require explicit reporting of search and selection procedures.	Provides a reporting reference; the current targeted search lacks records needed to claim a completed systematic review.
13	Kamicase Team (n.d.-a)	AMEF_Disenio_Gancho_Porta_Caliper	Internal project FMEA; directly relevant but not independent evidence	Lists potential design failure modes and internal severity, occurrence, and detection scores.	Provides the project's risk-screening basis; actions remain pending until implementation is documented.
14	Kamicase Team (n.d.-c)	Producción más limpia Poka-Yoke	Internal project report; contextual evidence	Identifies possible workflow interruptions and costs associated with improvised support practices.	Provides context but does not quantify actual rates of hose damage, incidents, or measured time savings.

Synthesis of the Literature

The reviewed sources support the need to keep a removed brake caliper properly supported and provide a conceptual basis for an error-prevention aid. However, the literature does not establish that the proposed hook, in its current modeled form, prevents detachment or is compatible with every vehicle configuration. Retention geometry, anchoring location, ease of placement, and the possibility of omitting the tool must be assessed explicitly.

SMED provides a useful lens for evaluating preparation and searching activities, but the estimated change from 10.0 to 8.8 minutes is not a measured result and cannot demonstrate a causal improvement. Similarly, the project FMEA identifies potential risks rather than observed failures. Its scores should be used as internal priorities and updated only after corrective actions have been implemented and verified.

Finite-element and material references support a cautious reading of the available static-analysis plots. The reported stress, displacement, strain, and safety-factor scales are useful for directing further checks, but the absence of the native model, load definition, contact settings, mesh-convergence evidence, and physical tests prevents a definitive conclusion about allowable load or operational safety. The main contribution of this review is to connect the available evidence to specific design decisions and identify remaining verification work.

THEORETICAL FRAMEWORK

The conceptual framework integrates three tools. First, Poka-Yoke provides a criterion for reducing the likelihood of errors while handling the caliper. Second, SMED helps examine time losses associated with searching, improvisation, and workstation preparation. Third, FMEA identifies potential failures and guides risk-reduction actions before the device is manufactured or used.

The relationship among these tools does not mean their results are interchangeable. FMEA identifies scenarios that could occur; it does not prove that the hook has failed or withstood a load. Calculating a difference between times summarizes estimates provided by the team; it does not replace a controlled experimental study. Finally, selecting AISI 1020 defines a material decision but does not automatically validate the design's strength.

Accordingly, the project is evaluated through four questions: (1) Is the concept and its material defined? (2) Have the relevant failure modes been identified? (3) What do the reported time and cost figures indicate? and (4) What evidence is still needed before the product can be considered safe, compatible, and effective?

Numerical verification examines whether the model consistently solves the defined case; physical validation compares predictions with actual behavior. Constraints, contacts, equilibrium, and convergence must be reviewed. Autodesk (n.d.) recommends comparing mesh refinements at geometrically consistent locations. A strength calculation alone does not demonstrate vehicle compatibility, retention, or durability.

METHODOLOGY

Study Design

An applied, descriptive, documentary engineering study was conducted, including secondary interpretation of simulation results. The unit of analysis is the assembly represented in the PDF "simulaacion estatica.pdf," added to the project file on October 24, 2026. The updated version contains five pages: four plots (stress, displacement, strain, and factor of safety) and one material data sheet. These are graphical outputs, not experimental replicates or evidence of independent load cases. No new simulations were run for this review.

Unit of Analysis and Sources

The unit of analysis consists of four static-simulation plots and an AISI 1020 data sheet. The FMEA and Cleaner Production documents, together with the render provided by the team, were also included. The native CAD file, dimensioned drawings, applied load, contacts, and mesh data were not included with the PDF. No prototype or physical tests exist. The render is an illustrative visualization, not evidence of manufacture.

FMEA Treatment

The seven rows in the design FMEA were transcribed, and the risk priority numbers (RPNs) were calculated from the S, O, and D scores recorded in the spreadsheet. The calculation is RPN = S × O × D. The values were

used to identify documentation priorities and recommendations. Because the action-completed and revised-score columns are blank in the reviewed file, recommended actions are presented as pending rather than implemented controls.

Time and Cost Treatment

The 10.0- and 8.8-minute values are estimates, as clarified by the team, although earlier documents call them averages. The projected difference is 1.2 minutes, or 12%. There is no measured sample from which to calculate variability, significance, or causality, and it has not been established that the values come from a process simulation.

The itemized budget from the Cleaner Production report was reproduced. The alternative figure of MXN 85 is recorded as a documentary discrepancy with no reconciled calculation basis in the reviewed files; it is neither averaged nor presented as equivalent to the MXN 265 budget.

Each datum was classified as a confirmed decision, preventive judgment, numerical result, operational estimate, or pending evidence. Units and plot legends were retained. The factor of safety was checked arithmetically against the yield strength and equivalent stress; this check does not replace mesh convergence or physical validation.

Literature Search and PRISMA Scope

An exploratory web search was used to locate official technical documents and identifiable publications on caliper supports, Poka-Yoke, and finite-element interpretation. PRISMA 2020 was used as a transparency-reporting guide, not as a quality certification or substitute for a method. The PRISMA-ScR extension may be relevant to a future mapping of solutions and evidence types (PRISMA statement, n.d.-a, n.d.-b). The present search is targeted and is not presented as a completed systematic review.

The initial exploration on October 23, 2026, used the queries “brake caliper” “hanger” “finite element,” “poka yoke” automotive maintenance systematic review, “caliper support hook” simulation, and “gancho” “caliper” “simulación.” The October 24 update added queries about ESTRN, URES, contacts, and convergence, directed at SOLIDWORKS documentation, as well as HELLA, PRISMA, and the steel supplier. No searches were conducted within Scopus or Web of Science.

The synthesis was narrative and organized by function, risk, and evaluation criterion. A complete inventory of retrieved records, duplicates, exclusions, and full texts assessed is unavailable; therefore, no flow diagram or number of included studies was invented. To complete a PRISMA-compliant review, the search strings for each source, dates, exported records, and reasons for exclusion must be retained.

RESULTS AND DISCUSSION

Result 1. Concept definition

The images show an upper hook connected to an elongated perforated body, a lower arm ending in another hook, and a diagonal bar connecting the two arms. Circular features are visible at the joints and appear consistent with pivots or pins, although their construction cannot be confirmed without drawings. The holes may allow adjustment, but they do not demonstrate a functional locking mechanism or establish dimensions, clearances, or travel. The selected material remains AISI 1020. Figure 1’s render communicates the design’s appearance; it does not establish dimensions, tolerances, or manufacturing finish.

The term Poka-Yoke is used here to indicate a preventive design orientation. The tool is intended to replace an improvised support with a more standardized operation, but it is not claimed to eliminate human error completely or to have validated retention. Before routine use is recommended, it must be confirmed that the hook cannot detach, does not interfere with nearby components, and can be anchored to a suitable point for the vehicle configuration.



Figure 1. Illustrative render of the hook provided by the team. Digitally generated visualization; not a photograph of a manufactured prototype.

Numerical evaluation of the assembly

The factor-of-safety screenshot identifies the model as “complete hook” and the study as “Static Analysis 1 (Default),” using an automatic criterion. The data sheet shows AISI 1020, a linear isotropic elastic model, and the maximum von Mises stress criterion. The software version, load magnitude, contacts, and mesh parameters are not shown. The outputs are arithmetically consistent with one another, but their full relationship must be confirmed in the native file.

Table 1. AISI 1020 material properties shown in the simulation data sheet (PDF, p. 5).

These are library input data, not results from a material test. The compressive-strength field is blank. Thermal properties are transcribed for traceability; they do not demonstrate that a thermal load was applied. The data sheet does not identify the material’s supply condition.

Equivalent von Mises stress

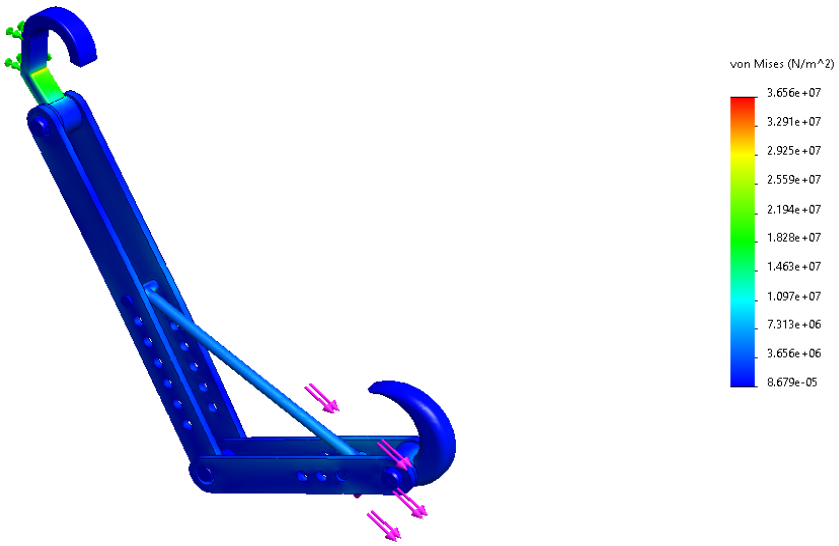


Figure 2. Equivalent von Mises stress. Source: Caliper Hook project team (2026), p. 1.

The scale in Figure 2 ranges from 8.679×10^{-5} to 3.656×10^{7} N/m². The upper limit equals 36.56 MPa. It is reported as the upper value shown because no nodal-maximum annotation or legend configuration is available. If the scale was manually adjusted, its endpoint does not necessarily correspond to the calculated maximum. The lower value is close to zero and does not describe the loading of the entire device.

The transition between the upper hook and its connection to the body shows higher colors than most of the arms. This distribution is consistent with a local concentration associated with the geometric change and load transfer toward the support. The image does not identify precisely the point that reaches the upper limit. Nor can it separate the geometric effect from the effect of constraints, which appear in the same general region.

The priority is to inspect this transition and compare local mesh refinements while keeping the same load case. Visser (n.d.) distinguishes a convergent stress concentration from a singularity whose stress increases as the mesh is refined. Neither can be diagnosed from color alone. A candidate improvement is to smooth the section transition, provided that the change is assessed while preserving hook clearance, mass, and analysis conditions.

Resultant displacement URES

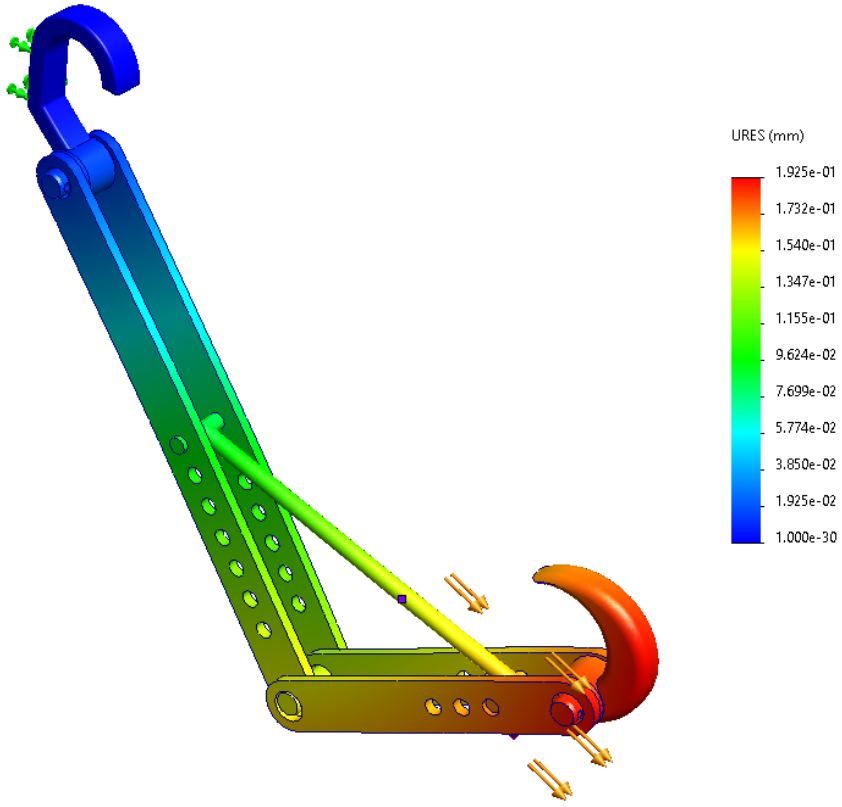


Figure 3. Resultant displacement URES. Source: Caliper Hook project team (2026), p. 2.

Figure 3 shows an upper scale limit of 1.925×10^{-1} mm, equivalent to 0.1925 mm or 192.5 µm. The URES legend represents the magnitude of resultant displacement, not exclusively vertical movement. Colors increase from the constrained upper hook toward the lower arm and hook. This distribution is consistent with one supported end and one loaded end, but it does not prove that the constraints reproduce actual contact with the vehicle.

The displayed lower limit, 1.000×10^{-30} mm, is effectively zero at the precision of interest. Its presence near the support is consistent with a motion constraint. It is not a physical measurement or a level of precision achievable in a workshop. The upper displacement on the scale is also not equivalent to the device's total elongation or the opening of the hook mouth.

Functional acceptance requires comparing relative displacement between contact surfaces, available clearances, and separation from the hose and nearby components. Without drawings, load, and tolerances, it cannot be established whether 0.1925 mm is acceptable or excessive. The proposed review should include relative movement at the joints and different adjustment positions, because high stiffness obtained through idealized joints may not represent the built mechanism.

Equivalent strain ESTRN

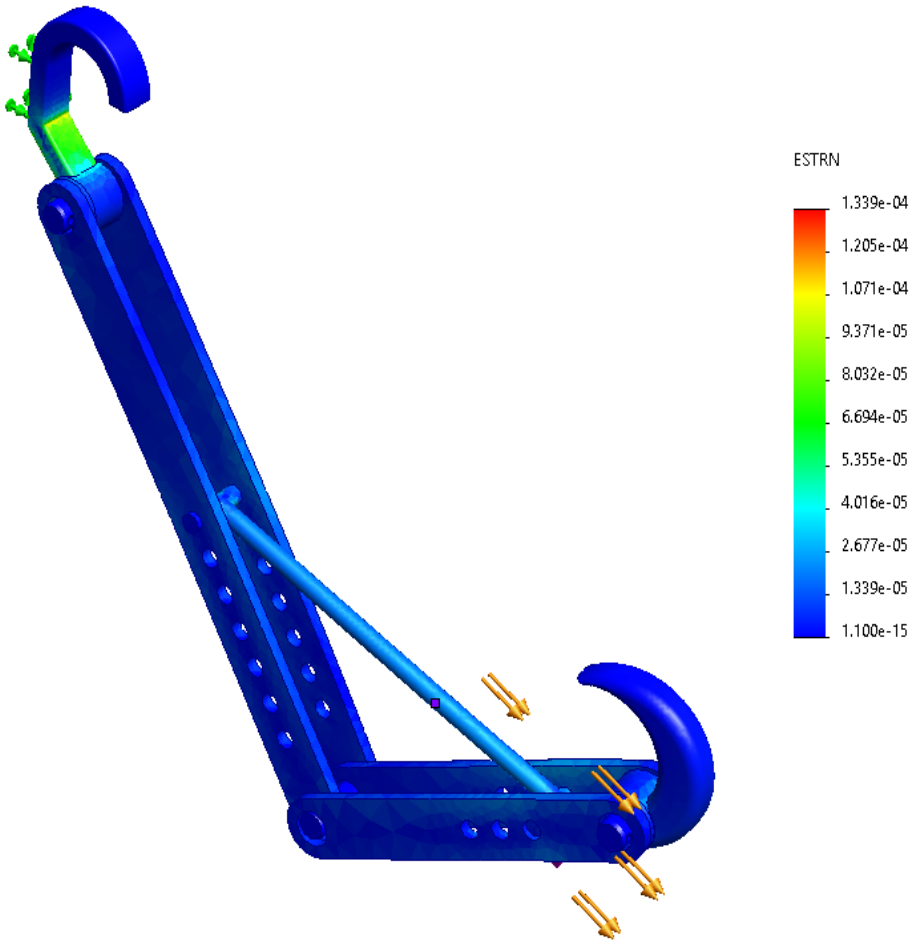


Figure 4. Equivalent strain ESTRN. Source: Caliper Hook project team (2026), p. 3.

Figure 4 shows an upper limit of 1.339×10^{-4}, equivalent to 0.0001339, 0.01339%, or 133.9 microstrain. ESTRN expresses an equivalent measure of local strain. It is not measured in millimeters and does not represent end displacement or the overall elongation percentage of the entire tool. The lower limit of 1.100×10^{-15} is numerically close to zero. Higher colors are concentrated at the upper-hook transition, qualitatively consistent with the stress plot. This regional overlap makes the area a priority for reviewing the results, but it does not demonstrate that the same nodes reach the extrema or confirm the material's elastic behavior. The supplied data sheet identifies a linear isotropic elastic law; its assignment to every component and the solved-case conditions must be checked.

Young's modulus should not be calculated by dividing 36.56 MPa by 1.339×10^{-4}: these are endpoints of two scales that may correspond to different locations and represent equivalent quantities under a multiaxial state. Taken together, the plots distinguish the region of greatest local stress near the upper support from the region with the greatest visible movement near the lower hook. This distinction suggests different improvements: geometric transition and load transfer in the first region, and stiffness and displacement compatibility in the second.

Factor of safety

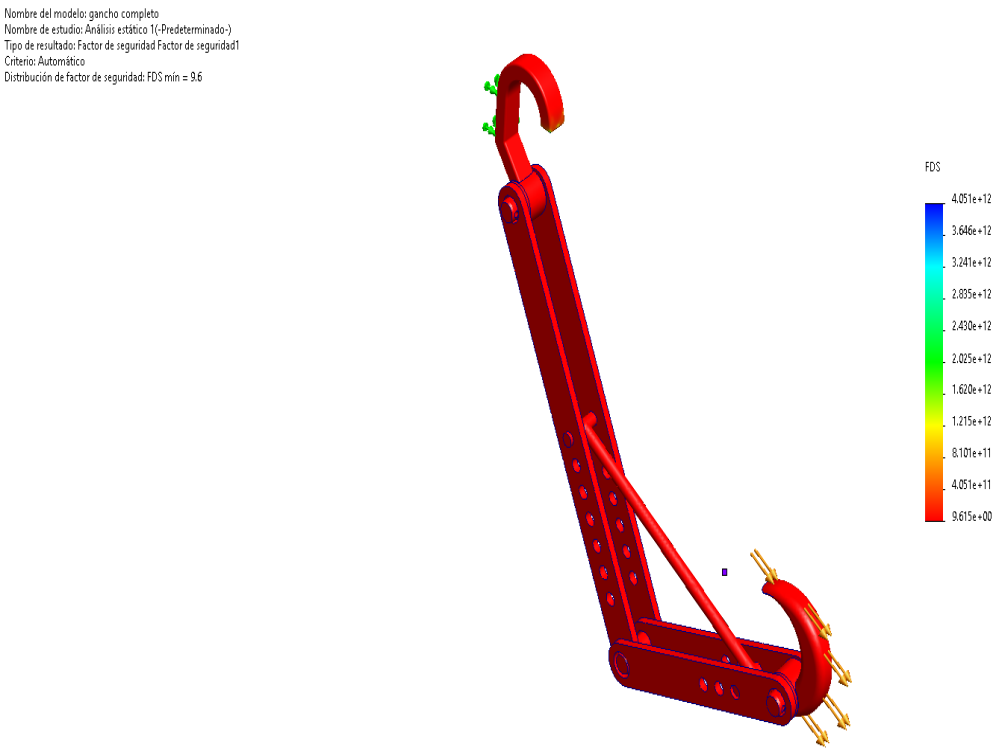


Figure 5. Factor of safety. Source: Caliper Hook project team (2026), p. 4.

The annotation states "minimum FOS = 9.6," and the scale shows 9.615 as its lower endpoint. Using the yield strength in the property table and the stress in Figure 2 gives 351.571/36.56 = 9.616. Within visible rounding, this agreement supports the interpretation that the factor was calculated against yielding using von Mises stress. The criterion relates a limiting stress to equivalent stress (Dassault Systèmes, 2016). This is a consistency check, not a reproduction of the study.

A minimum greater than one indicates a margin against the onset of yielding under the modeled conditions. It does not imply an allowable load 9.6 times greater, nor does it verify disengagement, fatigue, joints, or stability. The scale reaches 4.051×10^{12} where stress is close to zero; this endpoint does not represent usable physical capacity. Red marks the lower end of the factor-of-safety scale, not automatic failure. The graphical range should be adjusted around the minimum to distinguish critical regions. The data sheet defines a linear isotropic elastic material with E = 200 GPa, $\nu = 0.29$, and G = 77 GPa. The relationship $G = E/[2(1 + \nu)]$ gives approximately 77.52 GPa, a difference of about 0.68% from the tabulated value. The constants used by the solver should be verified; the data sheet should not be changed without checking the implementation. Library values must correspond to the actual supply condition.

Result 2. Failure mode and effects analysis

The FMEA contains seven potential failure modes. RPNs calculated from the scores in the file help rank the team's attention. The two highest values correspond to unintended disengagement and long-term corrosion or deformation. These results do not establish that the failures have occurred; they reflect the internal ratings recorded in the matrix.

Table 2. Design FMEA and internal priorities.

Potential failure mode	S/O/D	RPN	Recommended FMEA action
The hook fails to engage or detaches during service	5/3/3	45	Define the geometry; validate compatibility and consider a mechanical safety stop.

Fracture or plastic deformation under load	5/2/2	20	Perform a manual calculation or finite-element analysis using defined geometry and material.
Incompatibilidad con distintos cálipers	3/4/2	24	Probar configuraciones representativas y definir límites de compatibilidad.
Instalación difícil o con varias maniobras	2/3/2	12	Evaluar usabilidad y tiempo de colocación con un protocolo definido.
Corrosión o deformación en uso prolongado	4/3/3	36	Especificar recubrimiento y ejecutar pruebas de durabilidad apropiadas.
Aristas que dañan componentes	3/2/3	18	Revisar radios, acabado y holguras en las zonas de contacto.
Tool loss or unavailability	2/4/1	8	Define a fixed, visible storage location.

RPNs of 45 and 36 are the highest in this matrix and justify prioritizing retention and durability. Occurrence scores must not be interpreted as observed failure rates because the file contains no statistical failure history. In addition, the matrix's proposed actions have not been documented as completed, and no revised scores are available.

From a design-management perspective, unintended disengagement deserves priority because it could cause the caliper to fall and impose an unanticipated load on nearby components. Corrosion and deformation relate to maintaining function over time. However, the RPN does not replace physical testing or a documented assessment of the severity of a possible event.

Result 3. Estimated time scenarios

Table 3. Estimated time scenarios.

Indicator	Without hook	With hook	Correct interpretation
Estimated duration	10.0 min	8.8 min	Estimates confirmed by the team; no workshop timing data.
Absolute difference	—	1.2 min less	Arithmetic calculation using the estimated values.
Diferencia relativa	Referencia	12 % menor	Cálculo descriptivo, no prueba de significancia ni causalidad.
Tamaño de muestra y variabilidad	No existe muestra medida	No existe muestra medida	No es posible estimar incertidumbre estadística.

The relative difference is calculated as $100 \times (10.0 - 8.8)/10.0 = 12\%$. The arithmetic is correct, but it does not validate the input values. No comparable source reproducing these exact times was identified, and the service interval to which they apply was not defined. Therefore, 12% remains a projected scenario to be tested through repeated, documented workshop observations.

Result 4. Costs and documentary discrepancy

Table 4. Historical project budget.

Item	Basis stated in the report	Approximate cost
Tubular steel	1 m	$90 MXN
Welding	1 service	$40 MXN
Pintura anticorrosiva	1 aplicación	$35 MXN
Mano de obra	1 hora	$100 MXN
Total itemized budget	Sum of the four items	$265 MXN

The four items sum to MXN 265, matching the itemized budget in the Cleaner Production report. The experiment-design presentation (Kamicase Team, n.d.-b) also contains an alternative figure of MXN 85, but no equivalent breakdown was found in the reviewed files. The figures are therefore not treated as interchangeable.

The budget should be updated using the final geometry, actual material consumption, manufacturing operations, joining hardware, finishing, and labor.

Result 5. Manufacturing, safety, and environmental impact

The Cleaner Production report proposes operations such as cutting, bending, welding, and applying anticorrosion paint. These operations are described as a proposed manufacturing route, not as a confirmed sequence for the final design. Because other project versions mention different materials and configurations, the process must be reconciled with the final CAD model before it is used for cost or environmental estimates.

The documentation anticipates benefits such as less improvisation, lower risk of hose damage, fewer leaks, and reduced waste generation. The reviewed file set contains no measured evidence confirming these benefits. The functional basis is consistent with technical maintenance guidance: HELLA states that a removed caliper should be secured with a suitable hook and must not hang from the brake hose; the hose should also not be twisted or bent (HELLA, n.d.).

The device's functional rationale is consistent with technical maintenance practice: HELLA indicates that a removed caliper should be secured with a suitable hook and must not be left hanging from the brake hose; the hose should not be twisted or bent (HELLA, n.d.).

Evidence synthesis and pending validation

Table 5. Evidence synthesis.

Aspect	Evidence status	Next step
Concept and material	Concept documented; AISI 1020 confirmed by the team.	Include the actual CAD file, drawing, dimensions, and material specification.
Design FMEA	Documentary matrix with seven modes and scores; completed-action fields are blank.	Review scores and document the actions actually implemented.
Strength and retention	Four plots and AISI 1020 data sheet; minimum FOS ≈ 9.6. Retention not verified.	Document load, contacts, mesh, and reactions; assess retention and plan future physical validation.
Compatibility	Tests proposed in the FMEA; results are not documented in the project file.	Record vehicles, anchor points, clearance, and results for each configuration.
Times	Estimates of 10.0 and 8.8 min; projected difference of 12%.	Define the measured interval and record repetitions, technicians, and vehicles.
Costs	Itemized budget of MXN 265 and unreconciled alternative figure of MXN 85.	Confirm quantities, quotations, labor, and scope for both figures.
Impacto ambiental	Beneficios previstos, sin indicadores medidos.	Si se desean afirmar beneficios, medir fugas, residuos o retrabajos antes y después.

The evidence supports describing the design, interpreting four numerical plots, checking the factor of safety, and prioritizing risks. The numerical consistency supports the interpretation of the study, but the load, contacts, and mesh information needed to reproduce it are missing. Retention, compatibility, usability, and durability have not been demonstrated through physical tests.

FMEA identifies potential failures, whereas simulation estimates the response under assumptions. The render communicates the design but does not prove manufacture. The budget allows an arithmetic total to be reproduced, but it requires updating for the assembly with arms, holes, joints, and diagonal bar. These evidence types are complementary and should not be treated as substitutes for one another.

Proposed future verification and validation

The following activities are proposals to complete development, not tests that have already been performed. Acceptance criteria should be defined before testing, and tests should be conducted using safe work procedures.

Table 6. Proposed verification and validation plan.

Stage	Proposed activity	Minimum record
Definition	Freeze the CAD version, material, section, support points, and manufacturing process.	Drawing with dimensions, revision, material, and bill of materials.
Structural verification	Complete verification of the existing simulation and then plan physical tests.	Applied load, setup, displacement, strain, and acceptance criterion.
Retención y compatibilidad	Evaluar anclaje e interferencias en configuraciones vehiculares representativas.	Vehículo/configuración, punto de apoyo, estabilidad, holguras e incidencias.
Usabilidad	Observar colocación y retiro mediante instrucciones estandarizadas.	Operador, repeticiones, errores de uso, observaciones y tiempo.
Time study	Compare the same interval using an appropriate reference support and the proposed tool.	Individual data, sample size, cycle definition, and statistical summary.
Durabilidad	Inspeccionar desgaste, corrosión, deformación y retención tras ciclos definidos.	Número de ciclos, condiciones, inspecciones y fotografías.

CONCLUSION

Interpretation of the screenshots advances the caliper support hook from a conceptual description to a preliminary assessment of its numerical behavior. The scales show 36.56 MPa equivalent stress, 0.1925 mm displacement, and 1.339×10^{-4} equivalent strain. The upper-hook transition is the main region for further investigation because the stress and strain plots show higher values there. The displayed minimum factor of safety of approximately 9.6 is arithmetically consistent with the material yield strength and the upper stress-scale value, but it applies only to the modeled conditions.

The priority improvements are to review the upper transition, define the joints and adjustment lock, and evaluate retention. The FMEA confirms that structural response must be complemented by an assessment of disengagement. AISI 1020 matches the supplied data sheet; the material assignment by component and actual supply condition must still be verified. No physical prototype or physical test results are available, so safety, vehicle compatibility, and service durability cannot yet be claimed.

The MXN 265 budget is arithmetically consistent but must be reviewed for the final assembly and reconciled with the alternative MXN 85 figure. The project currently includes a preliminary numerical evaluation, an FMEA, and a visual representation. To complete verification, the load case, constraints, contacts, mesh convergence, manufacturing drawings, and acceptance criteria must be documented. Subsequent physical tests should assess retention, caliper compatibility, hose clearance, adjustment, repeated use, and durability. The estimated 12% time reduction remains a hypothesis until validated by repeated workshop measurements.

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Ethics Approval

This manuscript analyzes documentation from an engineering project and does not report research involving human or animal participants. If subsequent usability tests with technicians are conducted and data are collected for research purposes, applicable institutional requirements must be determined and documented before the study begins.

Conflict of Interest

No information indicating conflicts of interest was identified in the reviewed documents. All authors should confirm this statement before submission.

Data Availability

The evidence consists of four numerical plots and one material data sheet in the project file. The native file, model parameters, and nodal data were not included with the reviewed PDF. No time-study records are available for the scenarios presented. The render is included for illustration; drawings and physical test results are not available.

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