SAND2020-5539PE

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ENGINEERING AND DESIGN PROJECT WORK

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PROJECT PROBLEM STATEMENTS

Static Fire Redesign	DynaTense	Dust Explosions
To prepare a static-fire test stand for upcoming motor tests by refining the design to increase modularity and conducting tests and analyses to determine the maximum load capacity of the test setup.	To deign the two mechanisms in a medical device which will be inserted into a resected, reduced knee joint prior to femoral bone cuts, and which will create a distraction force on each condyle and measure the resultant gap between a patient's proximal tibia and distal femur.	To analyze factors relevant to catastrophic explosions in dust-heavy environments and provide simple countermeasures to increase safety, protecting employees and company assets.

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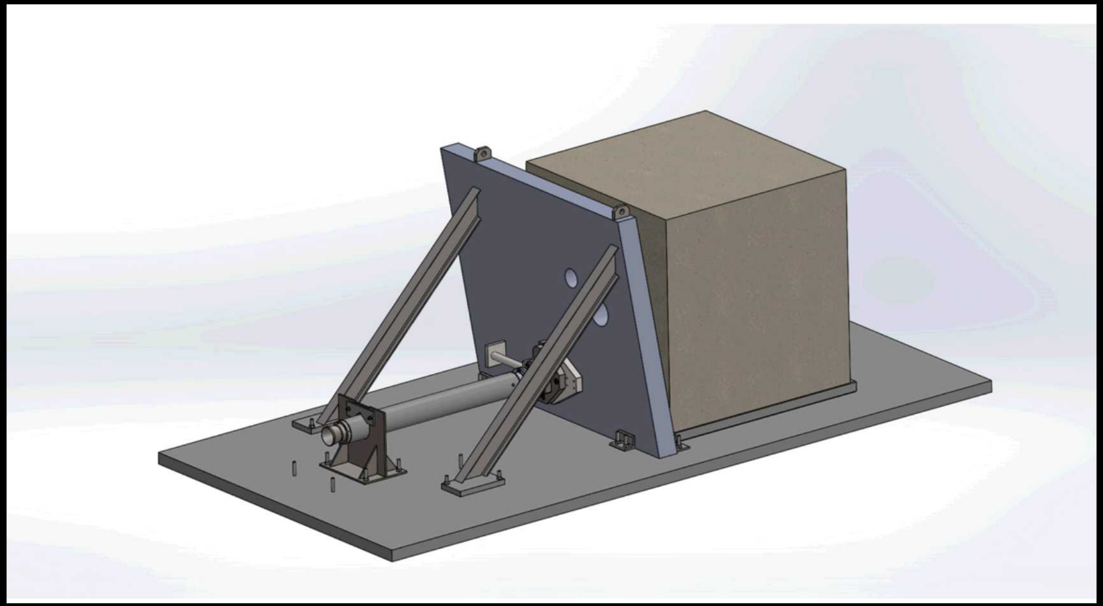
STATIC FIRE TEST STAND REDESIGN AND CAPACITY ANALYSIS

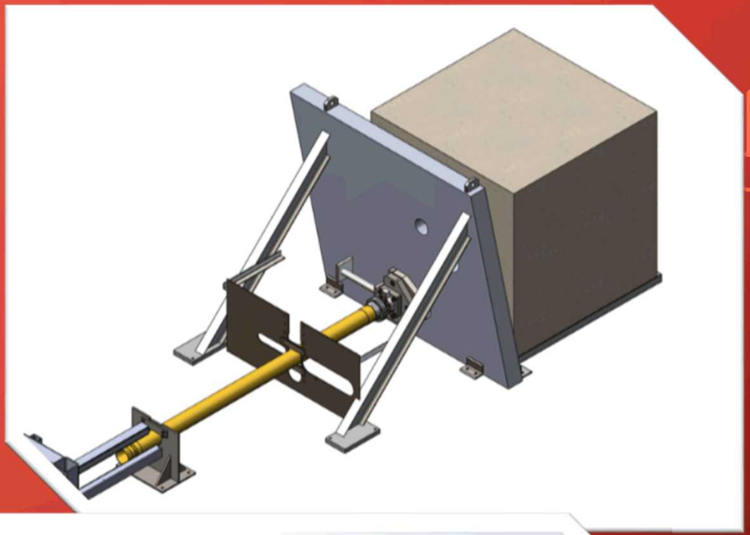


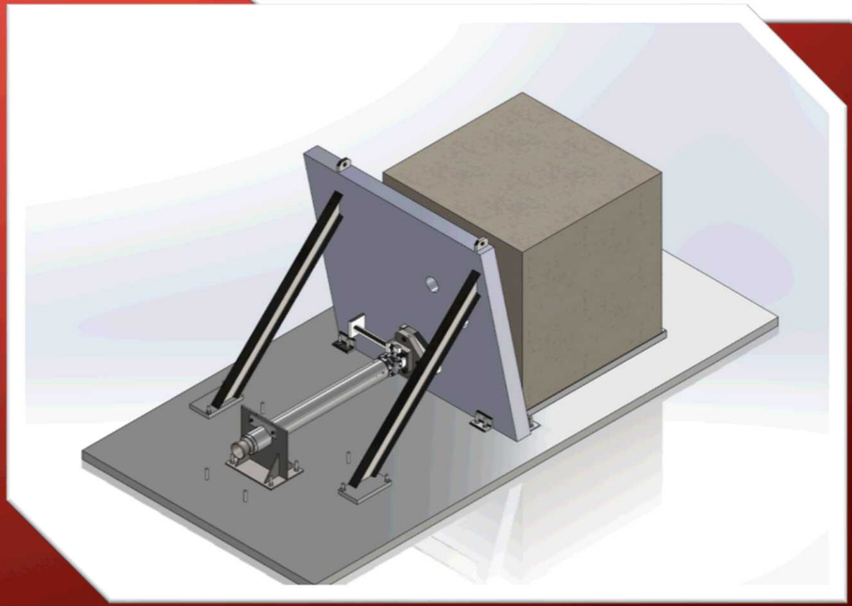
BACKGROUND

- SNL static fire test stand
  - Used to determine motor thrust output profile
  - Issues with current design:
    - Old, material & design specifications unknown
    - Non-removable mid-motor support plate
    - Unknown motor thrust capacity

DESIGN CONCEPTUALIZATION - MODULARITY

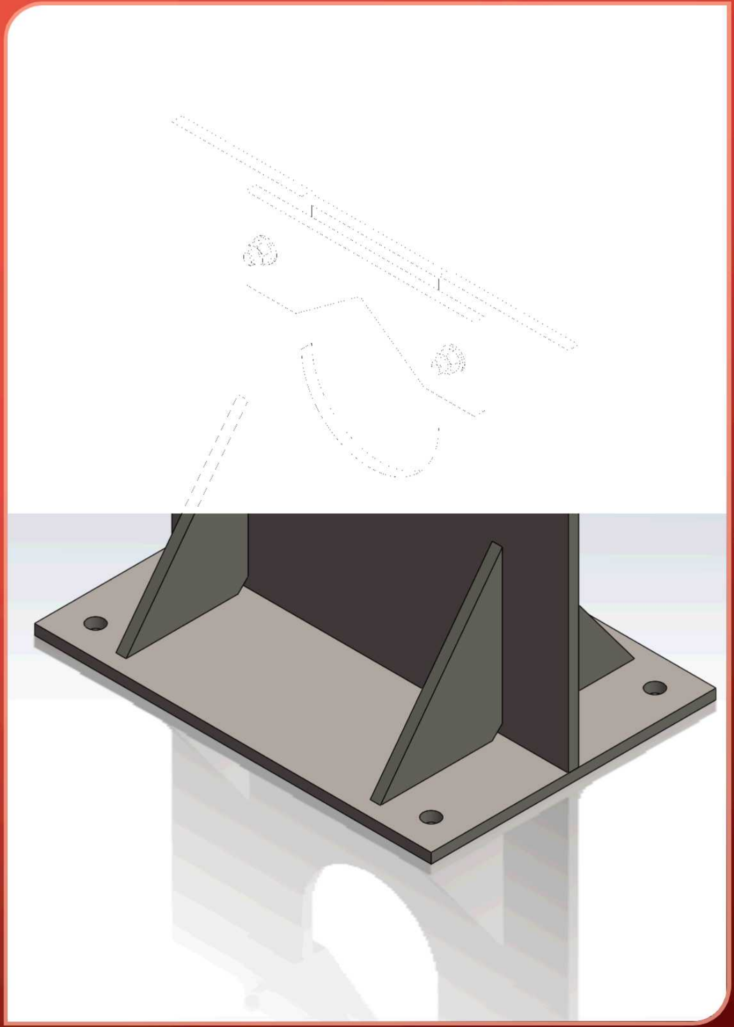
- Removal of welded, fixed-diameter forward support.
- Motor modelled from manufacturer specifications to appropriately design mounting.
- Test setup model updated to include anchor points, concrete, and more accurate reflection of actual structure
- Attachment of new motor adapter to load cell.





AFT STAND REPLACEMENT

- New positioning of aft stand to account for removal of forward support
- Larger diameter motors than previously tested
- Adjustment in holding brackets to ensure static system
- Simple to manufacture and install, can be replaced when the situation requires



CAPACITY ANALYSIS STEPS

1. Determine Material Properties
2. Designate likely modes of failure
3. Generate assumptions
4. Simplified preliminary hand-calculations
5. Finite-element analysis
6. Data Evaluation

MATERIAL PROPERTY DETERMINATION

- Test Structure
  - Weight and appearance of metal components suggest steel
  - Communication with staff convey that weakest material likely used is A36 Steel
- Concrete Base
  - Mechanical Test Hammer utilized to determine concrete surface hardness
  - Concrete surface hardening due to age – no more than 33%

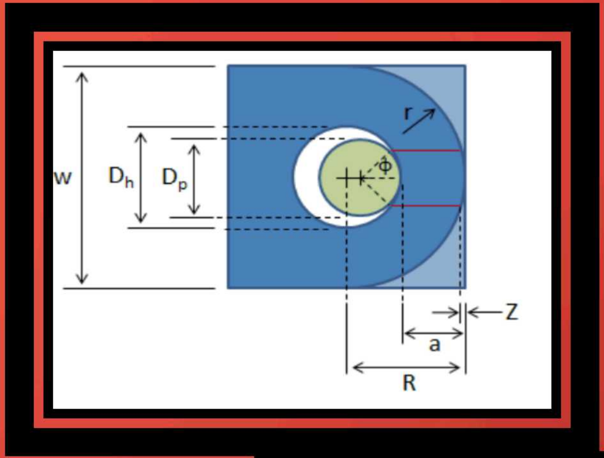
POTENTIAL MODES OF FAILURE

- Anchor Shaft Failure
- Ground Bracket Failure
- Pull-out of Concrete Anchor
- Concrete Cone Failure
- I-Beam Failure

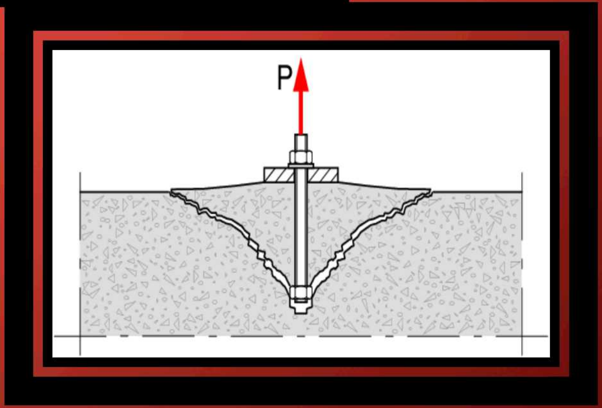
ASSUMPTIONS USED

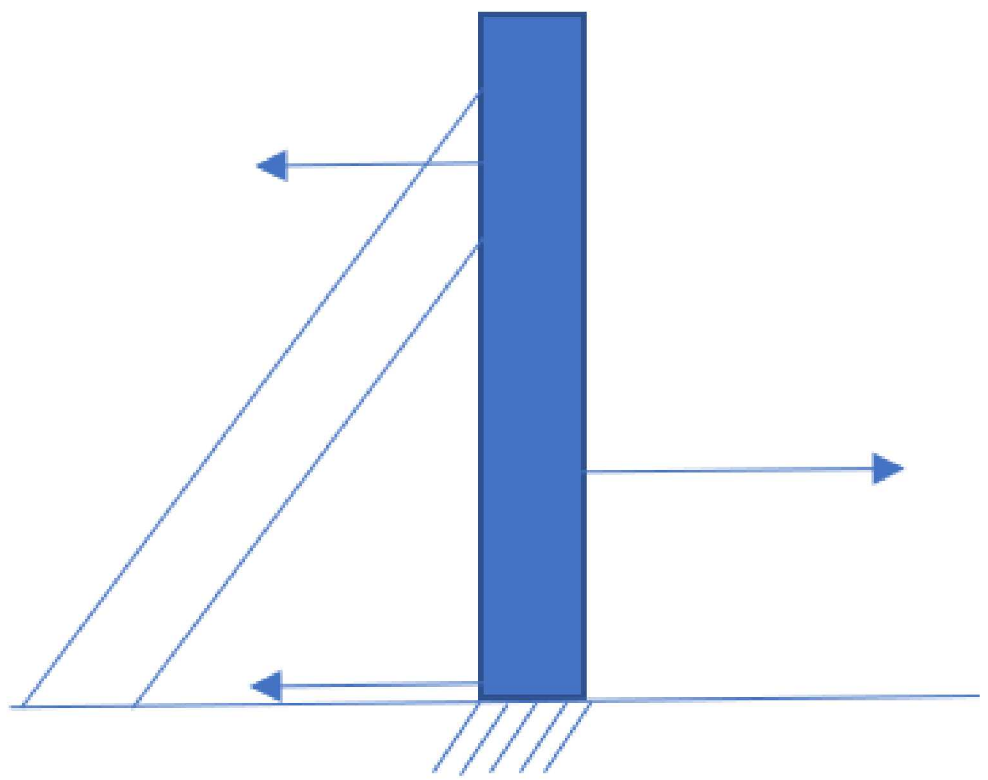
- All structural steel has material properties according to ASTM A36.
- Concrete is lightweight, high-strength concrete with f'c = 6000 PSI, and the surface strength is no more than 133% of the body strength. The concrete block weighs approximately 18125 lbf.
- Concrete anchors are RED HEAD brand Trubolt Wedge Anchors with .75" diameter embedded 3.25" into the ground.
- Thrust Force is evenly distributed along motor adapter.
- Shear Strength = 0.6 * Tensile Strength
- Threaded Section of Concrete Anchors specifications according to AMS 5860
- Force required to strip thread = Ultimate Shear Stress * Thread Area
- The coefficient of friction between the concrete and the steel is u = 0.1.
- The failure of the brackets follows the model of failure in a lug.

POTENTIAL MODES OF FAILURE



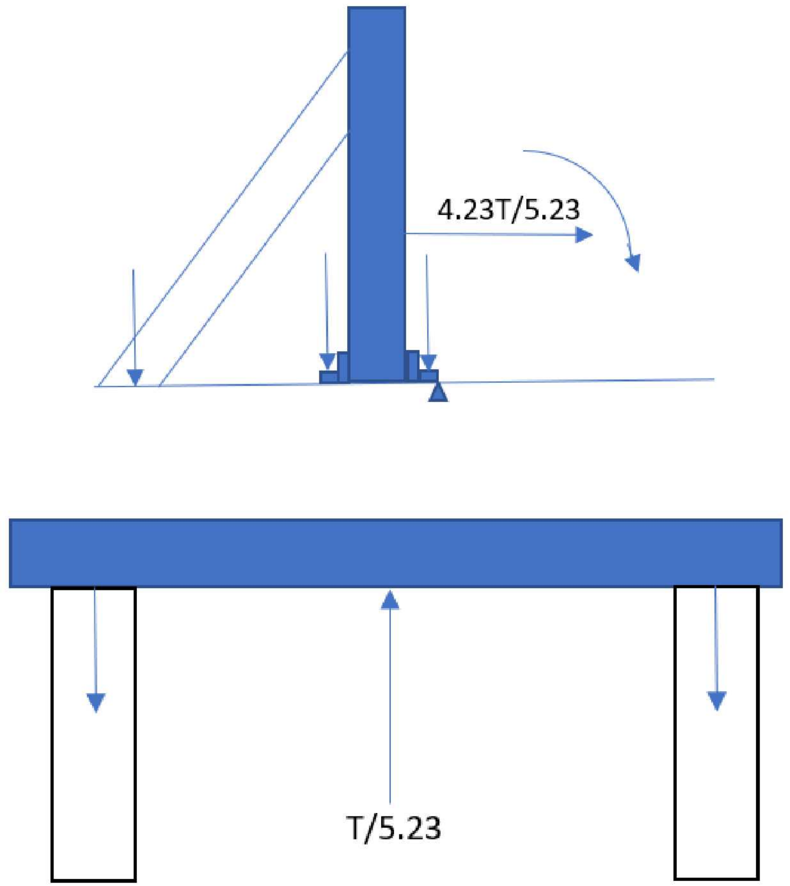
- Anchor Shaft Failure
  - Values taken from specification sheets of concrete anchors
  - Tensile, Shear, Stripping failures
- Ground Bracket Failure
  - Calculation of values for bearing, net tension, and shear tear-out failure
- Pull-out of Concrete Anchor
  - Values taken from specification sheets of concrete anchors
- Concrete Cone Failure
  - In accordance with CCD model, with 40% strength lost from cracks due to age
- I-Beam Failure
  - Potential failure in weld HAZ





DESIGN VERIFICATION – SIMPLIFIED BEAM MODEL

- Approximation as static 2-Dimensional beam with fixed support at ground, pin support at I-Beams, and motor thrust as point force.
- Reaction forces at the strut and base are characterized by the following equations, where T is the maximum motor thrust and F_f is the frictional force provided by the concrete block at the rear:
  - $F_{X-IBeam} = \frac{T}{5.23}$
  - $F_{X-Base} = T - (\frac{T}{5.23}) - F_f$

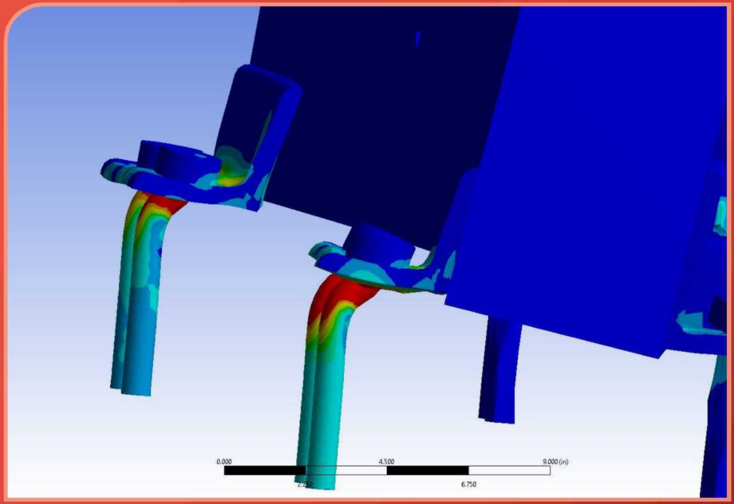


DESIGN VERIFICATION – SUBSEQUENT MODELS

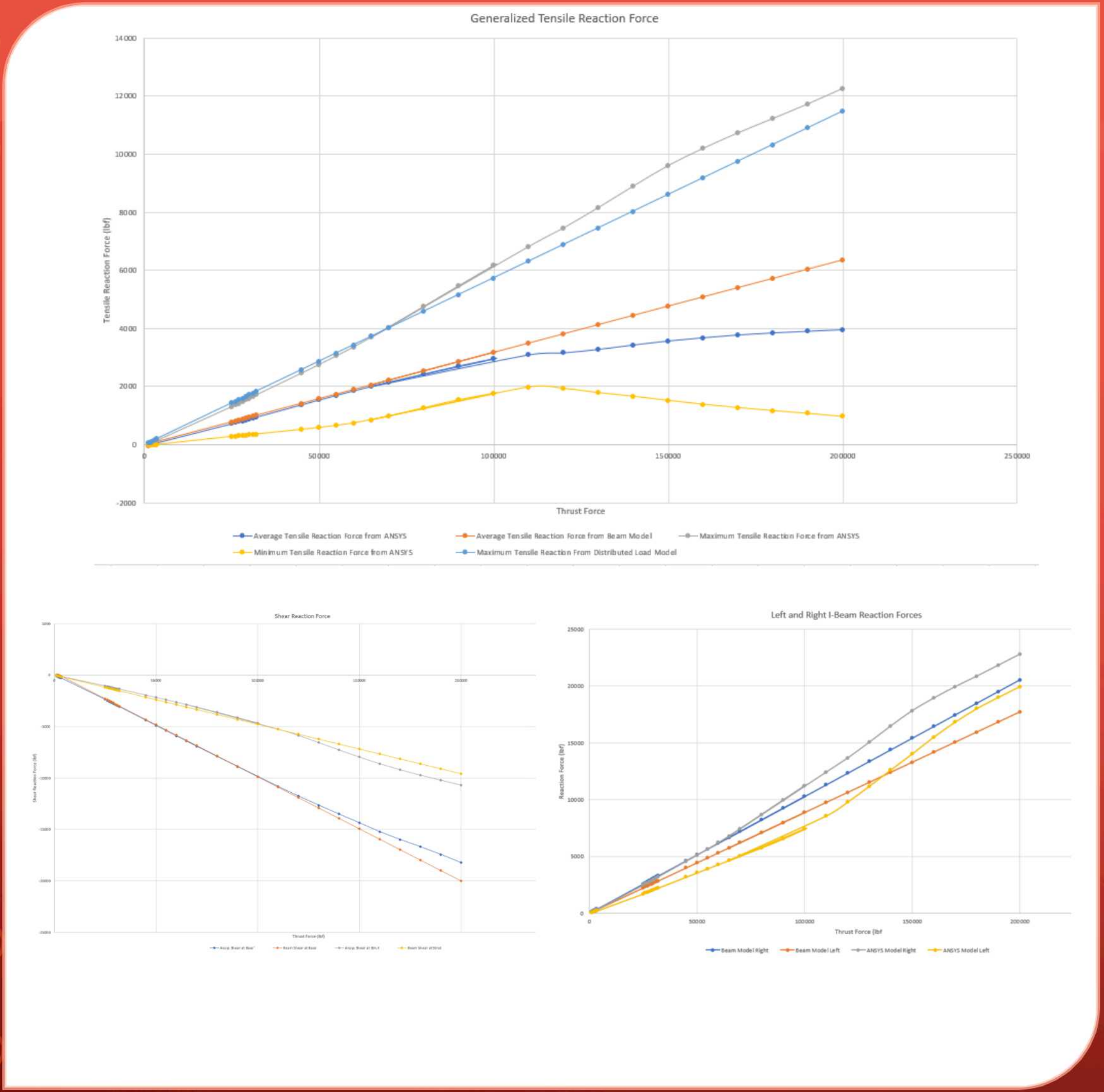
- Single body anchored at 12 points
  - $T_{max} = \frac{Rhr_{max}}{\sum r_n^2} = 0.0574R$
- Beam model moment reaction
  - $T_{avg} = .0397(T)$
- Top-down beam model I-beam reactions
  - $F_{Right} = .537(\frac{T}{5.23})$
  - $F_{Left} = .463(\frac{T}{5.23})$

DESIGN VERIFICATION – FINITE-ELEMENT ANALYSIS

- Inputs: parameterized thrust force
- Contact surfaces adjusted until reactions occurred as expected
- Mesh sizing based on plastic deformation occurring in components
- Plasticity enabled to reflect changes in reaction as deformation occurs
- Outputs: total equivalent stress, total deformation, shear stress, I-beam axial forces, bolt reaction forces



DESIGN VERIFICATION – FEA COMPARISON



- Resultant reactions for motor thrusts between 0 and 200000 lbf via hand calculations and ANSYS simulations
  - X-direction forces at base brackets and strut
  - Average and maximum Y-direction bolt reactions
  - Left and right I-beam axial forces
- Results line up, especially at low thrust values

CONCLUSIONS

- New anchor points installed, easily removable aft stand and brackets manufactured
- Points of failure identified –safety factor of 1.3 to plastic deformation and 5.5 to fracture
- Design recommendation – increase bracket strength with stronger material, widen edges to prevent shear tear-out

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DUST EXPLOSION PREVENTION IN WOODSHOPS, SAWMILLS, AND GRANARIES

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FAILURE ANALYSIS OF A UNIVERSAL JOINT BEARING