

DESIGN ANALYSIS OF THE NATIONAL IGNITION FACILITY KINEMATIC PIN (NIFKP) OR FLEXURAL PIVOT

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ABSTRACT

A kinematic pin is a flexural pivot used for precision positioning. Many NASA contractors have successfully applied flexural pivots in space programs [1]. Some space program in optical communication system requires high precision design considering micro-yield stress [2] and dimensional stability of the material [3]. Kinematic pins designed for maintaining sub-micron position of focusing magnets in a particle accelerator have been successfully designed [4]. Flexural pivots are also used as seismic isolators for earthquake safety design in seismic industries [5, 6]. The NIFKP is designed for precision performance and earthquake safety. It is used to register a system as a reference position in a laser beam line. The reference position is maintained by three NIFKPs on balancing of forces of these pins [7].

INTRODUCTION

The National Ignition Facility (NIF) is a high power laser facility for fusion research and development. The project's design philosophy modularizes the laser's optical subsystem components into Line Replaceable Units (LRU) for ease in maintenance over its expected 30-year life. The LRUs are transported between the Optics Assembly Building (OAB) and the laser structure by a robotic material handling system. A major component of this handling system is a portable clean room, or canister, which seals the optics of the LRU during transport between the OAB and the laser from ambient air. The canister itself contains robotic systems that move the LRU into a position inside the clean laser cavity, once the canister is docked to the laser's enclosure. The bottom-loading canister carries a variety of different LRUs for placement in different portions of the laser with a permanent carriage platform, which elevates the LRU from underneath the laser enclosure to the laser system. Guiding a set of NIFKP into a precise position are the receptacles mounted on the bottom of the LRU elevating system. Once docked, the canister becomes the reference from which the robotic insertion mechanisms inside the canister load the LRUs into the laser beam-line. The NIFKP is shown in Figure 1 without the seismic support. The LRU and the elevating system used in the demonstrated design sample weigh over 2000 pounds. Each NIFKP is subjected to 750 pounds vertical load for normal operation. Horizontal force developed from the vertical load is limited to 300-lb maximum depending on the surface contact resistance. Load limiting stops transfer excessive seismic load to a seismic pin jointed at the bottom of the NIFKP assembly. Finite element method (FEA) is employed to solve the complex stress and deflection with microyield limit. The NIF seismic pin that supports the NIFKP uses post-elastic stiffness and energy dissipation to controlling the seismic response.

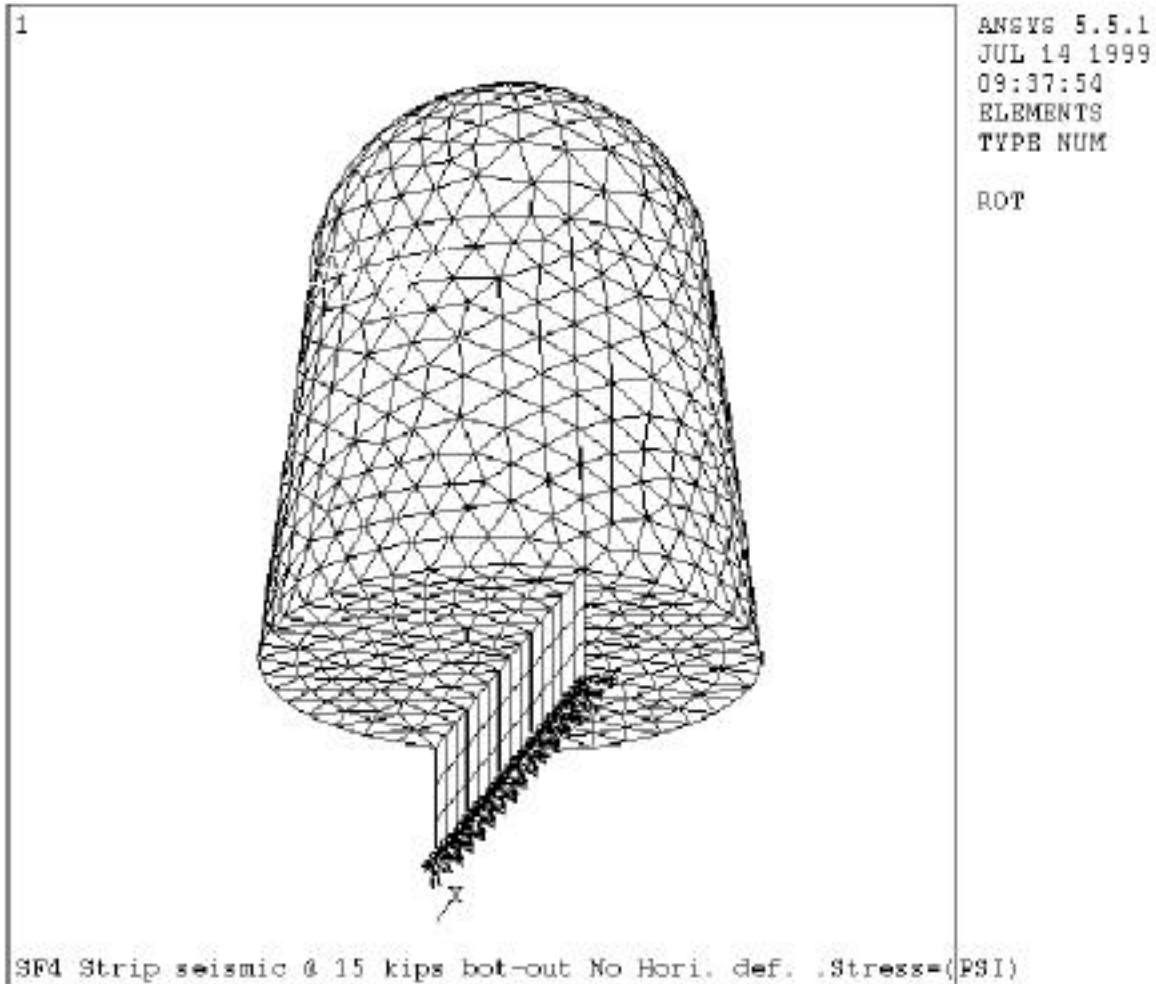


Figure 1. Finite Element Model of the NIFKP with A Conical Head for Docking.

The seismic analysis of the NIF component and receptacle [8, 9, 10] have been reported. To support the LRU in a level position with stability, the ball end must in full contact to the conical cavity of the receptacle (Fig. 2 line B-B). Optimizing the NIFTKP strip height and cross section is necessary for repeatability in precision positioning by observing the micro yield limit.

The NIFKP as shown in Figure 1 is designed to support a 2250-lb LRU with positioning accuracy within 0.025 in. The NIFKP machined from 440C stainless steel to form a ball end integrated with a flexural strip in dimensions as follows: 1.25”(height), 0.28”(width) and 0.03”(thickness).

A Seismic support designed to joint to the NIFKP, is served as an isolator to modify the system frequencies. The method for such design and analysis to avoid the system frequency within the critical range of the NIF site earthquake spectra has been reported [8]. The paper predicts that the NIFKP design has met all the requirements. (1) 0.0250 inch in horizontal deflection. (2) 750-lb vertical load. (3) Under the capacity of the horizontal force generated by the dead weight of the LRU. (4) To have the maximum combined stress, 145 ksi (Figure 3) within the micro stress limit. (190 ksi Stainless Steel.)

The NIFKP as reported in the present paper can support a 2250-lb weight LRU for docking to a specified position within a 0.025 inches. Owing to the maximum strain developed in the flexural strip is less than one part per million of the material elastic limit, we are confident that the requirement of 30 years high precision positioning performance of the NIFKP has been met.

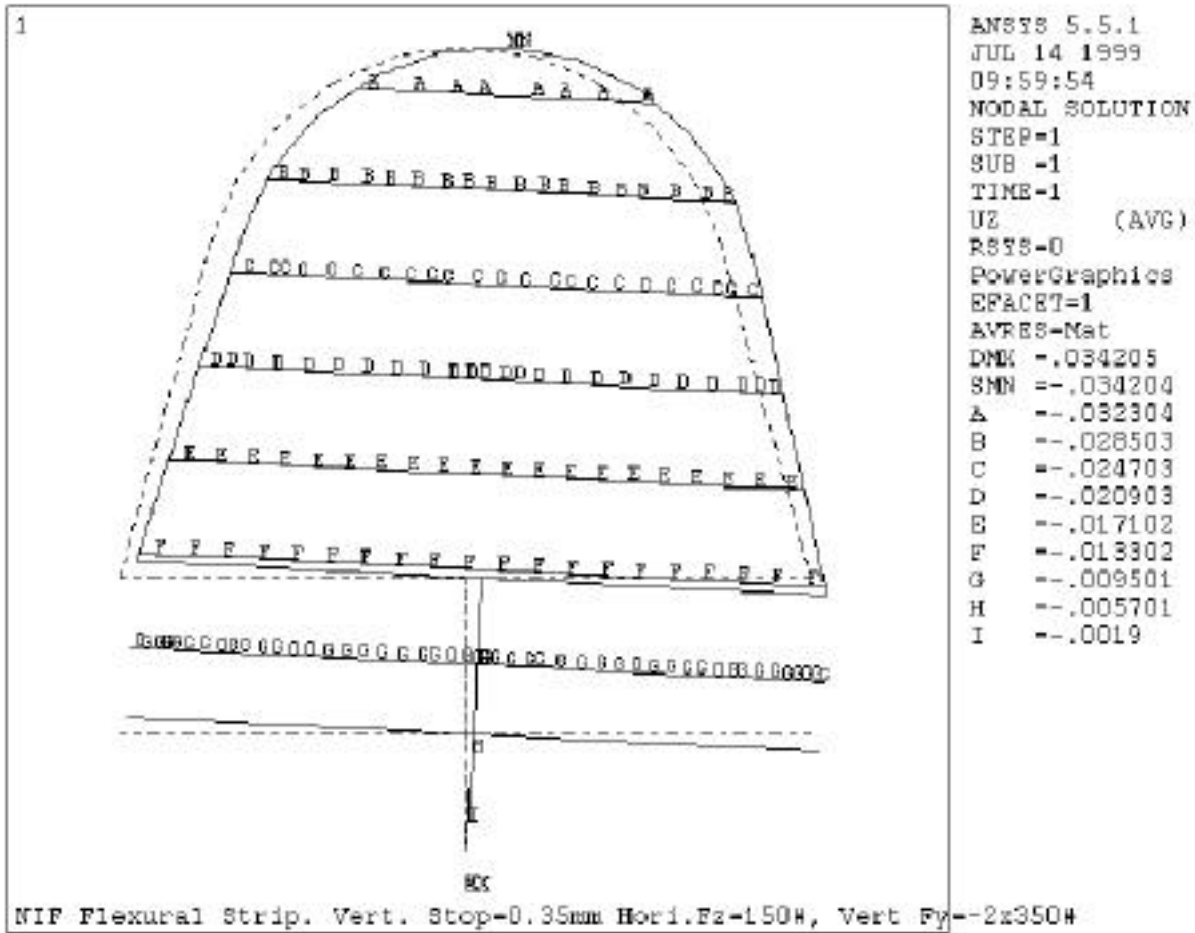


Figure 2. NIFKP under 2250 operational load and specified maximum horizontal movement of 0.0285", and vertical bottom out movement of 0.35 mm.

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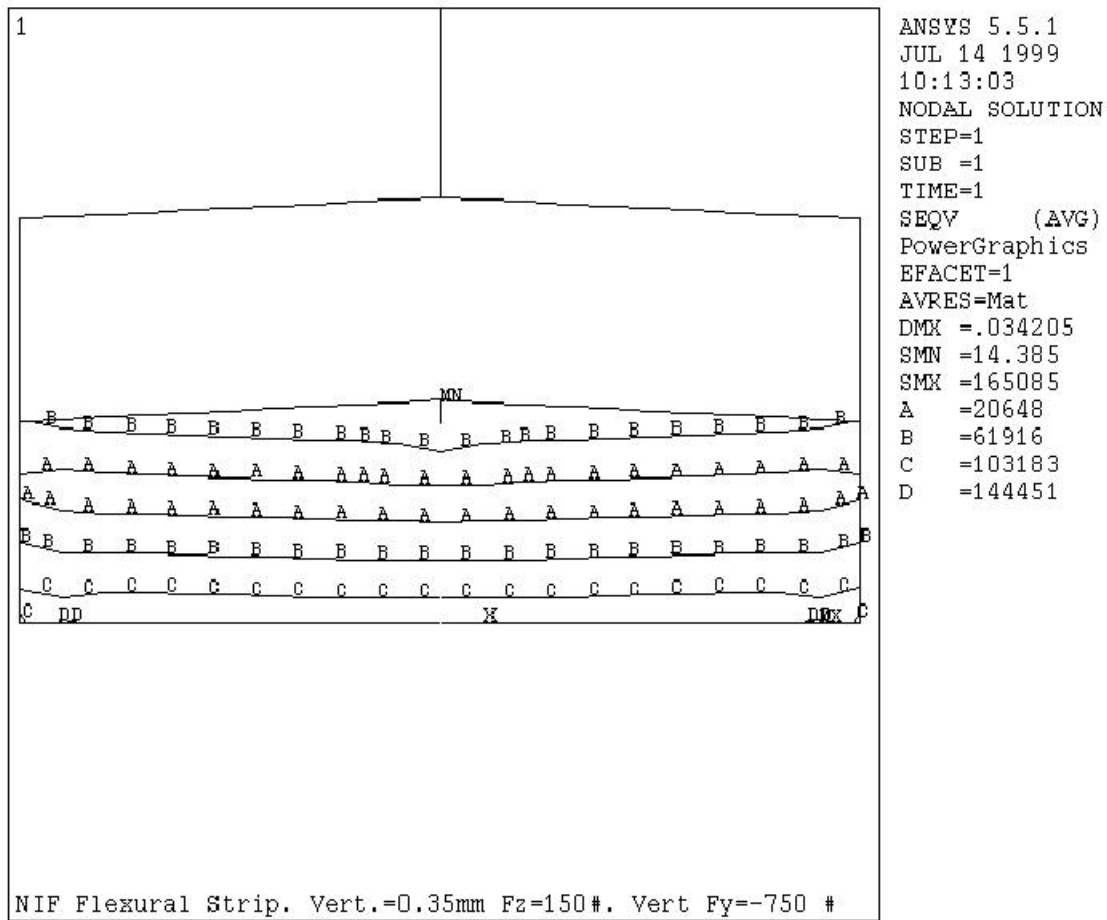


Figure 3. Maximum von Mises stress on the strip of the NIFKP under 2250 operational load and specified maximum horizontal movement of 0.0285", and vertical bottom out movement of 0.35 mm. The 156 ksi is less the micro yield stress limit for the material SS 440C.

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