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N-SHAPED AXISYMMETRIC ELASTIC ELEMENTS FOR STRAIN GAUGED FORCE TRANSDUCERS

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Abstract: Only few types of flexible structures are recommended for measuring very large forces. The axisymmetrical ones are best suited in this respect, their maximum strain gauge (tensometrical) sensitivity being ensured in bending. The force transducer body is easy to design by 2D finite element method (FEM) and easy to manufacture. Numerical investigations on various models of N-shaped strain gauged elastic elements are presented together with their advantages in the field of force measurements.

Keywords: N-shape, EE (elastic element), SG (strain gauges), FT (force transducer), FEA (finite element analysis).

1. INTRODUCTION

N-shaped elastic elements of strain gauged force transducers, as presented in Figure 1, have two cylindrical tubes of different diameters, concentrically telescoping one another, and a conical tube interconnecting their opposite ends [1].

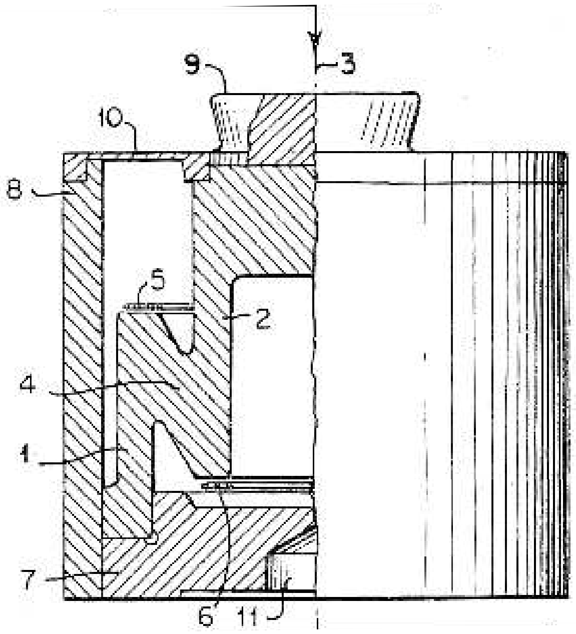


Fig. 1. N-shaped axisymmetric SGFT elastic element.

For such complicated elastic structures analytical formulae do not exist, designers working based on their experience and intuition in this multi- and inter-disciplinary field of electrical measurement of mechanical quantities.

Nowadays the numerical investigation using the finite element method is more than necessary for improving the design rate and accuracy [2].

2. PURPOSE

As a challenging development trend and following valuable researches within the Brain Pool Program of KRISS, we formulate a standard FEM procedure [3] for axisymmetrical elastic elements of strain gauged force transducers using ANSYS structural analysis.

A special attention is necessary to obtain proper strain diagrams on the sensitive sides of the elastic element measuring section, because it is essential to compare these diagrams in order to establish the best positions for strain gauges.

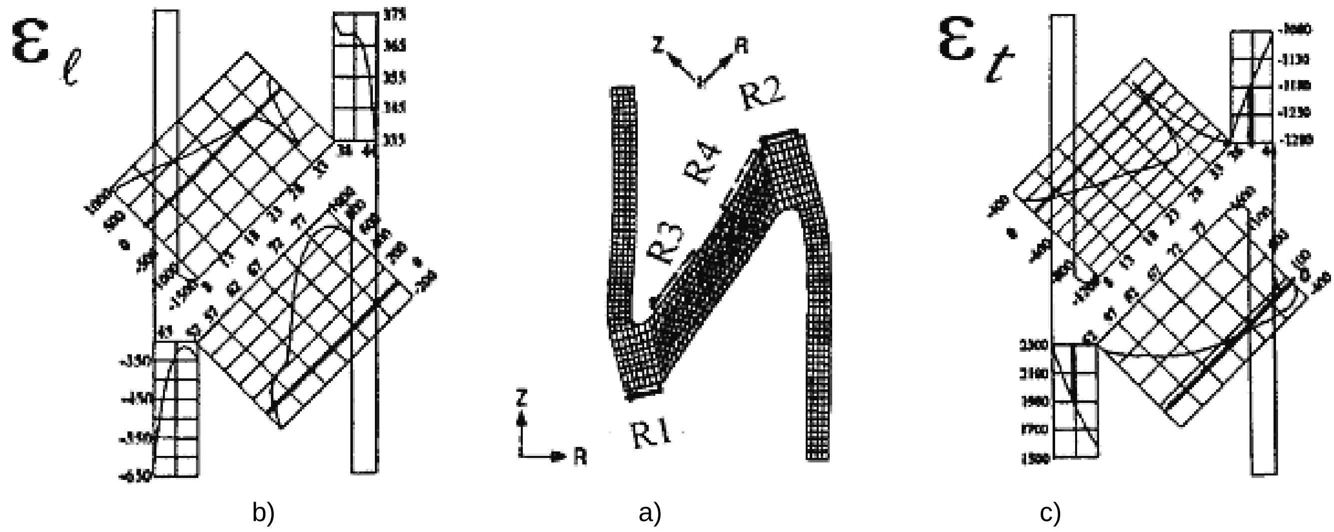
Appropriate paths for strains have to be conceived and plotted each time on graph, more precise and suggestive than plotting on geometry.

3. METHODS

Trying for the first time in the world [4] to systematize the wide range of the axisymmetrical elastic elements for the comparative analysis of the strain diagrams (ε), either longitudinal (l) or tangential (t) ones, a special computing programme, original and compatible with NASTRAN has been utilized.

The results of the analysis on the N-shaped section, axially loaded with F = 50 kN, are shown in Figure 2. The elastic deformations at the scale 71:1 are presented in Figure 2,a, surrounded by the strain diagrams ε_l (Fig. 2,b) and ε_t (Fig. 2,c).

One has to remark the "mixed" positioning of the strain gauges: two longitudinal and two tangential, their connection in Wheatstone bridge being represented in Figure 2,d.



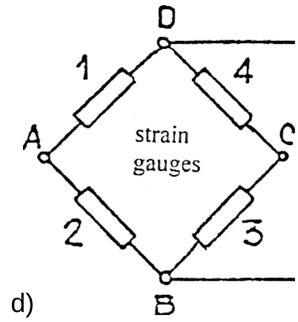


Fig. 2. N-shaped axisymmetric elastic element of strain gauged force transducer:

- **a) mesh generation and elastic deformation;**
- **b) longitudinal strain diagram;**
- **c) tangential strain diagram;**
- **d) Wheatstone bridge connection.**

Continuing our initial research and extending 20 times the force range, from 50 kN to 1 MN [5], we envisage the following steps for N-shaped elastic elements design optimization:

- Mechanical – establishing the optimum measuring range and overall dimensions for universal application of this new one-piece solution;
- Numerical – iterative FEM computation (2D analysis by ANSYS program based on Plane42 finite elements) for choosing the best axisymmetrical profile, to increase the measurement sensitivity;
- Electrical – designing special strain gauges and choosing their optimal positions on the elastic body (tangential versus longitudinal) and Wheatstone bridge connections to improve the measurement accuracy and other metrological characteristics.

4. RESULTS

Starting with Figure 3, we present several models of N-shaped elastic elements, which have been, in time, numerically simulated, trying to attain several important objectives:

- decreasing of the elastic element height;
- embedded protection for 100 % overload;
- enhancing of its tensometric sensibility;
- obtaining of magnitudes ε_{max} and ε_{min} as close as possible in absolute values (nearly 2000 μm/m);
- optimal positions establishment for strain gauges.

We prefer the realization of customized strain gauges, as "doublets" of circumferential strain gauges, placed on the superior and respectively inferior side of the N-shaped elastic element.

We observe that the minimum height is obtained when we realize oblique slots, which allow connections with bigger radii, favorable for reduction the stress concentrators. It is derived, in fact, a new type of axisymmetrical elastic element, which has the sensible section like a horizontally placed "S".

Comparing with the initial patent [1], our solution has more advantages:

- one-piece, sturdy and easy-to-use construction;
- FEM optimized elastic element having in view the best tensibility, i.e. tensometric sensibility;
- more balanced ± ε values;
- specialized circumferential strain gauges, perfectly adapted to the chosen model of SGFT;
- customized models for different ranges of strain gauged force transducers.

Evolving from the model presented in Figure 4 to that from Figure 5, the ratio $\varepsilon_{min} / \varepsilon_{max}$ increases from 0.6 to 0.75, and the tensometric sensitivity of all strain gauges increases with an average of 40 %.

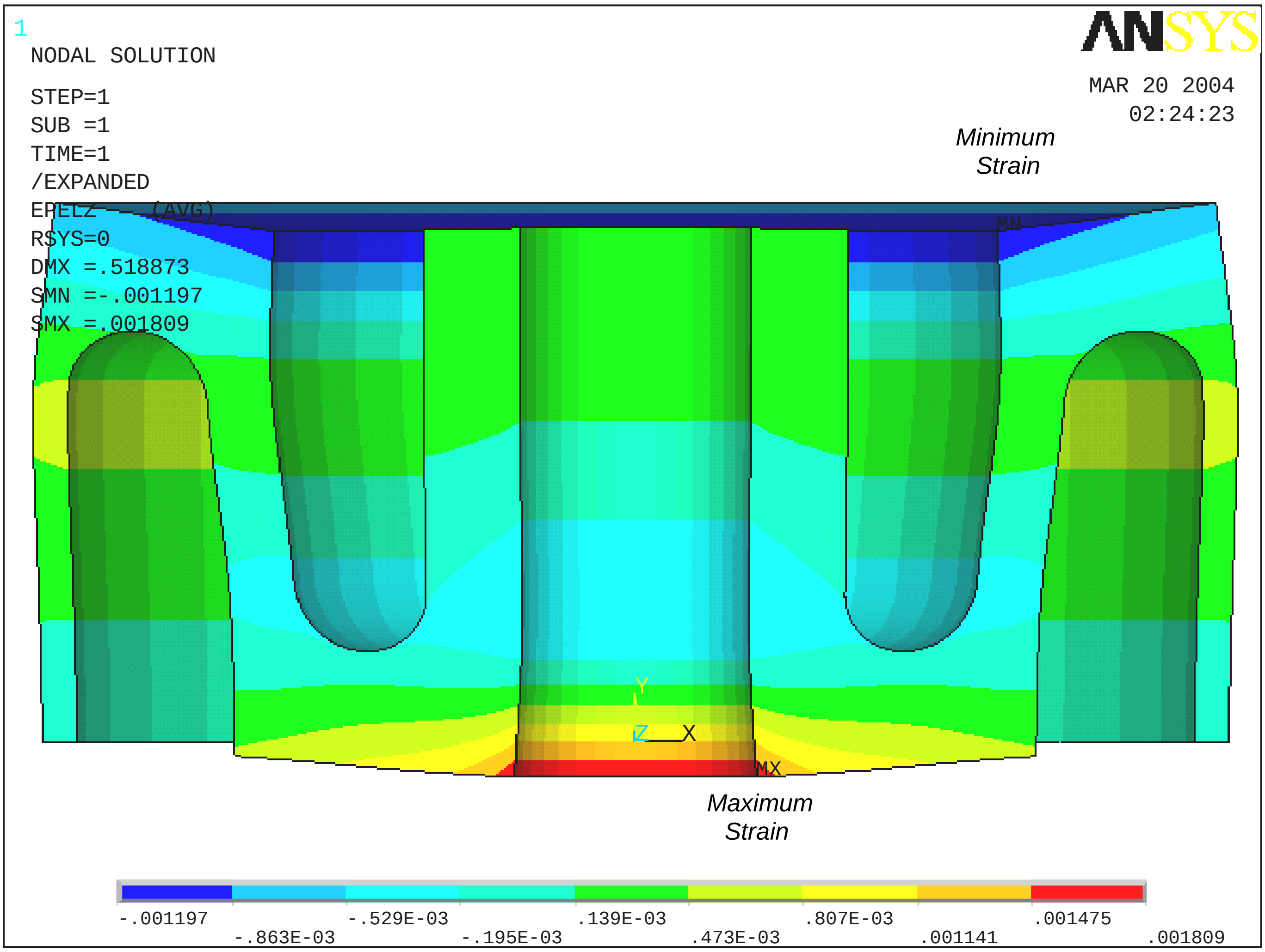


Fig. 3. Initial model simulation for N-shaped axisymmetrical elastic element of strain gauged force transducer.

A complex and suggestive representation of the deformed N-shaped elastic element, together with the associated circumferential strain diagrams on the superior and, respectively, inferior sides of the axisymmetrical "N", and the Wheatstone bridge connection, are presented in Figure 6.

5. CONCLUSIONS

We propose a new type of elastic structure for strain gauged force transducers having all advantages of force transfer standards and, particularly, the following ones [6]:

- Minimum possible height and weight for strain gauge solution, the most popular and used technique for electrical measurement of mechanical quantities;
- Special axisymmetrical shapes for the active sections – original design models, more sensitive than other uncustomized solutions;
- Structural optimization of the force transducer elastic elements during the design stages using refined models in order to establish the best shape and the proper dimensions of the SGFT measuring section.

6. POTENTIAL APPLICATIONS

Here are some promising applications of the N-shaped axisymmetric elastic elements for strain gauged force transducers:

- On-site calibration of large testing machines in different industries (ship and aerospace building, rolling mills, civil engineering, etc);
- International comparison and technical expertise within sustainable development for countries without developed metrological infrastructure.

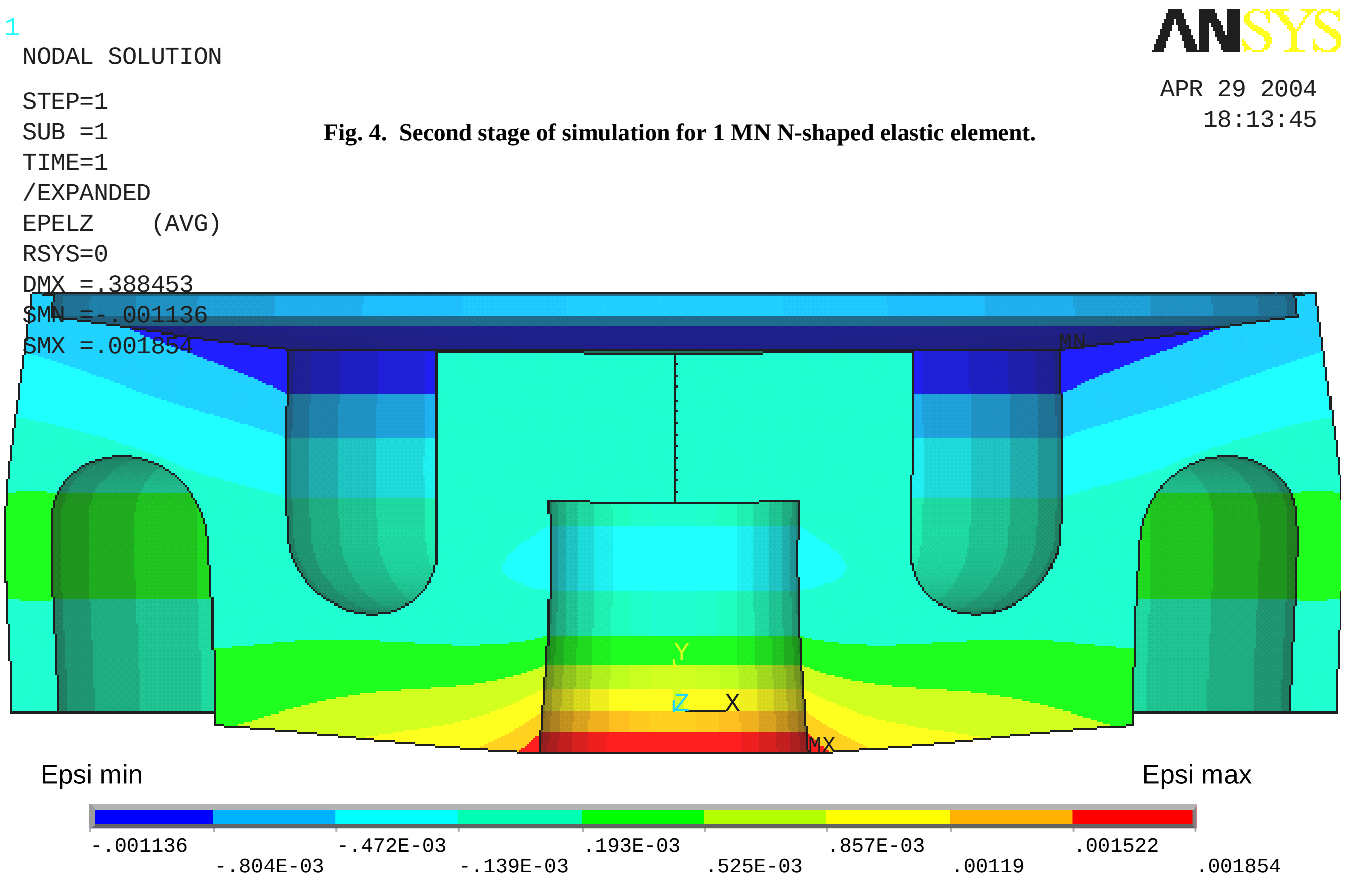


Fig. 4. Second stage of simulation for 1 MN N-shaped elastic element.

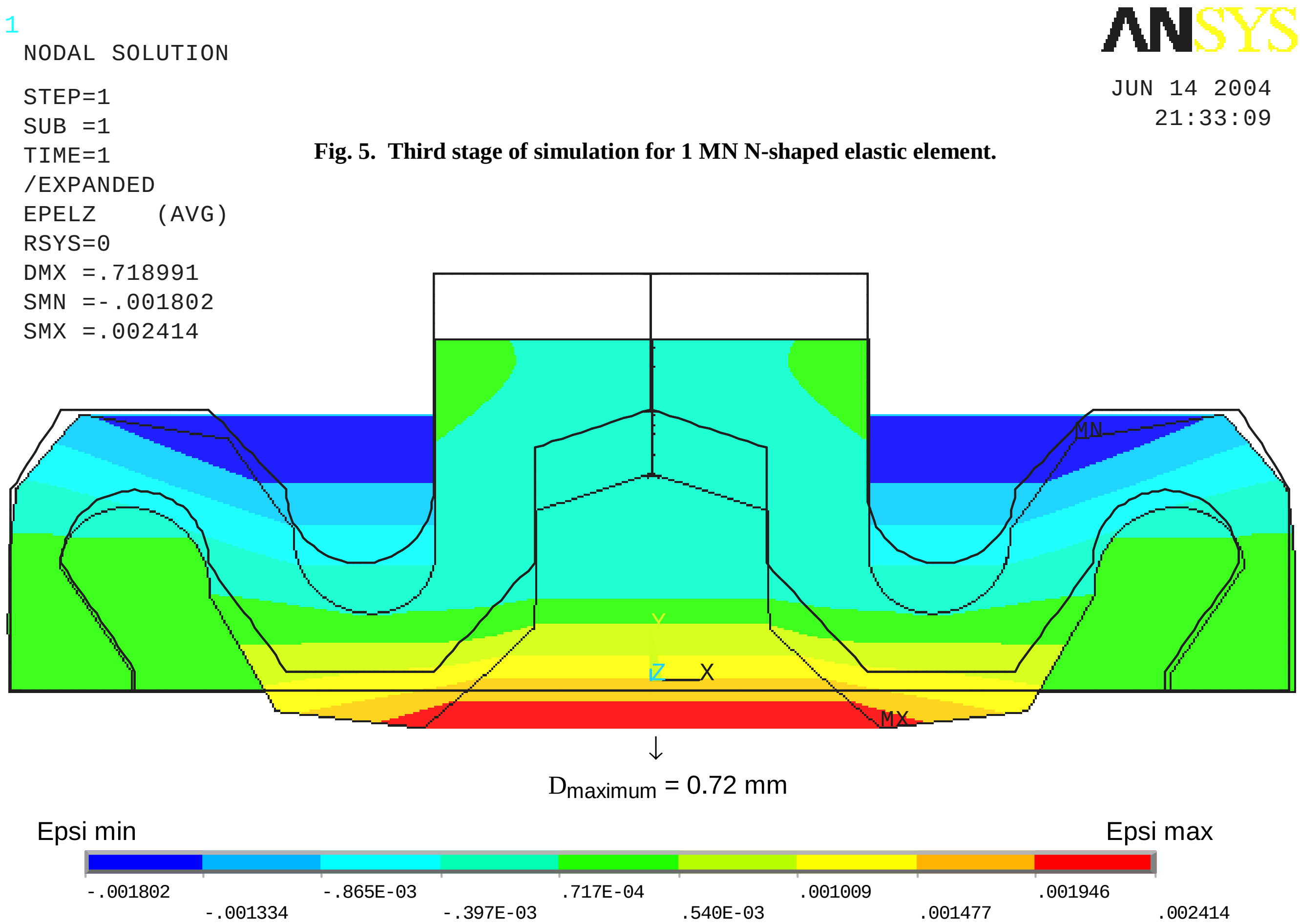
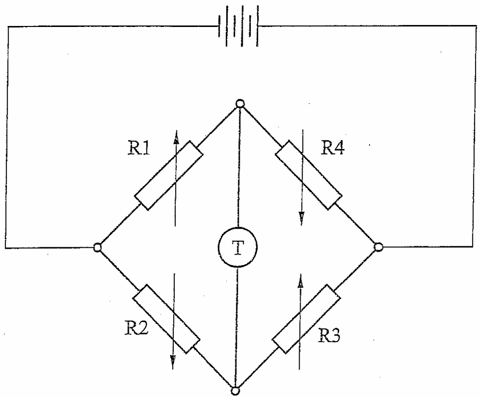
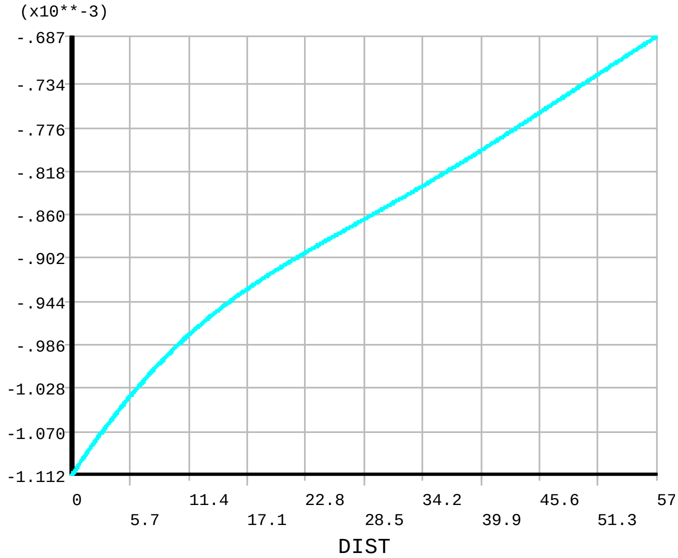


Fig. 5. Third stage of simulation for 1 MN N-shaped elastic element.

Circumferential strains

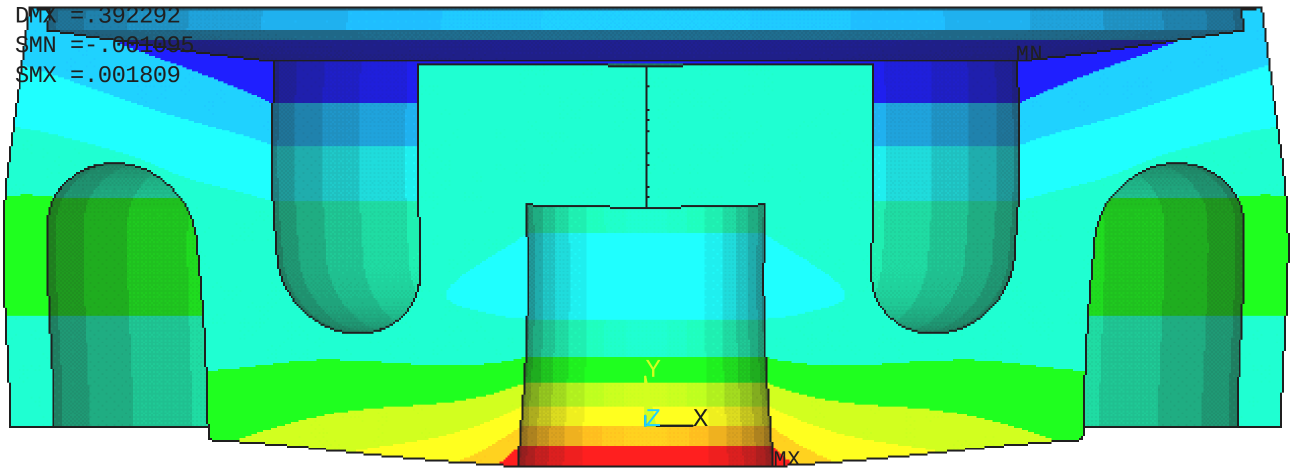


Wheatstone bridge



Epsilon diagram on the superior face of “N”

R2 (R4)



R1 (R3)

Epsilon diagram on the inferior face of “N”

Circumferential strains

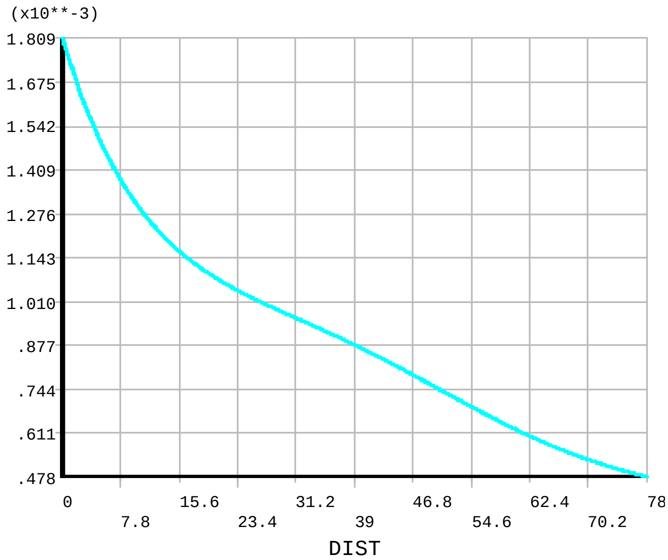


Fig. 6. N-shaped axisymmetric elastic structure for 1 MN strain gauged force transducer.

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