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Experimental Investigation and Numerical Analysis on Water Jet Nozzle

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Abstract:

Water jet nozzles are used for increasing the pressure of water coming out of the nozzle. The water comes out in the form of a jet from the outlet of a nozzle, which may be fitted to a pipe through which the water is flowing under pressure. The aim is to do the design of the nozzle using industrial standard design codes. The design and manufacturing process of a water jet nozzle is a cumbersome engineering challenge because of the extreme pressure conditions of the water.The nozzle has been designed in Pro-E software and analyzed using Ansys and manufactured on Computer Numerical Control machine (CNC Lathe). The nozzle is composed of an aluminum body with taper sector at one end and the other end slightly step turned. The aluminum material is specially selected for its light weight and less cost.A full literature review was carried out and used as a basis for the justification and to collate the relevant theory that was available.

1. Introduction:

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe [1]. A nozzle is often a pipe or tube of varying cross sectional area, and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them. In nozzle velocity of fluid increases on the expense of its pressure energy [2].

The main aim of the nozzle model here is to with stand the pressure load acting on the inner wall of the nozzle i.e.80 bar.The main areas of interest of the above analysis is to observe the deflections on the structure and stresses developed in the body because of applied load.

Key words:

Design of the nozzle,pressure acting on inner wall,deflections on the structure,stresses developed in the body due to pressure.

2. Modeling:

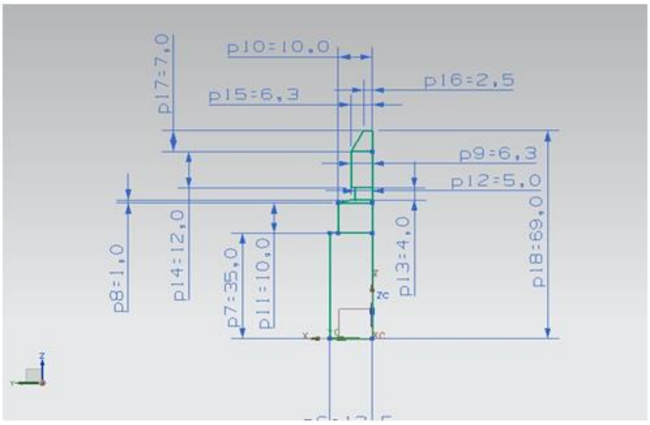

Fig.2.1 2D sketch of Nozzle

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Fig.2.2 Nozzle Model

3. Analysis:

The objective of the project is to perform structural analysis on a given nozzle part.Pressure load acting on the inner wall of the nozzle is 80 bar.The main areas of interest of the above analysis is to observe the deflections on the structure and stresses developed in the body because of applied load.

Material Properties of the nozzle:

The material used for the construction of nozzle and the mechanical properties are:

Meterial 1: Aluminum

Young's Modulus (E) =70Gpa

Poisson's Ratio = 0.3

Frictional coefficient: 0.2

Element Type Used:

Plane 182

Number of Nodes: 4

PLANE 182:

PLANE182 is used for 2-D modeling of solid structures. The element can be used as either a plane element (plane stress, plane strain or generalized plane strain) or an axisymmetric element. It is defined by four nodes having two degrees of freedom at each node: translations in the nodal x and y directions.

The element has plasticity, hyper elasticity, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials.

PLANE 182 Geometry:

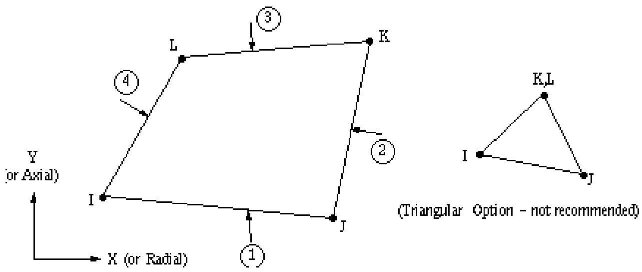

Fig: Plane 182

The geometry and node locations for this element are shown in Figure: PLANE182 Geometry. The element input data includes four nodes, a thickness (for the plane stress option only), and the orthotropic material properties. The default element coordinate system is along global directions. You may define an element coordinate system using ESYS, which forms the basis for orthotropic material directions.Element loads are described in Node and Element Loads. Pressures may be input as surface loads on the element faces as shown by the circled numbers on Figure: PLANE182 Geometry. Positive pressures act into the element. Temperatures may be input as element body loads at the nodes. The node I temperature T(I) defaults to TUNIF. If all other temperatures are unspecified, they default to T(I). For any other input pattern, unspecified temperatures default to TUNIF.

3.1 Generation of 2D and 3D model in Ansys:

The 3D model of the part was developed in ansys.Model was generated by taking advantage of axissymmetry as shown in the below figure.

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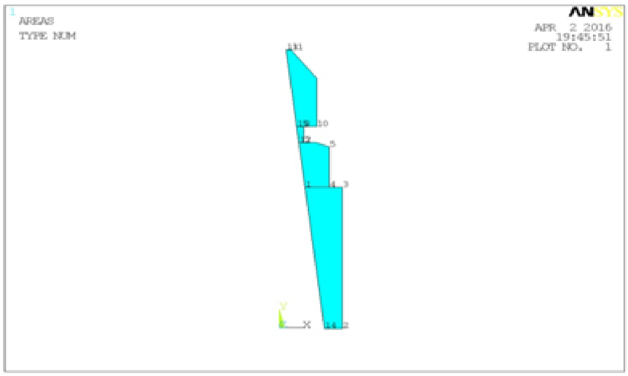

Fig3.1 2D model of the nozzle

Finite Element Model of part:The model is meshed using 4 node 182 element type.It is a 4 node element.The below figure shows the Finite Element Model of the part.

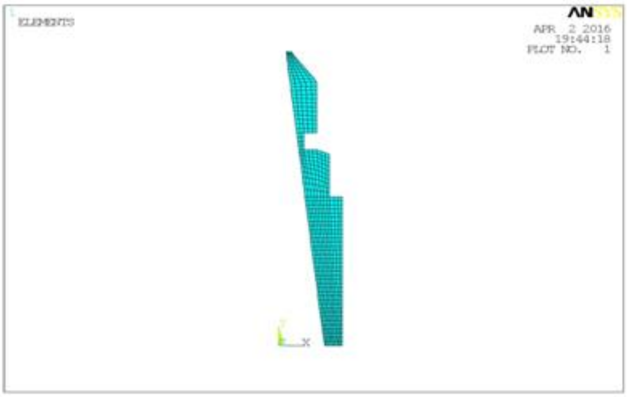

Fig.3.2 2D meshed model of the nozzle

3D meshed model of the nozzle:

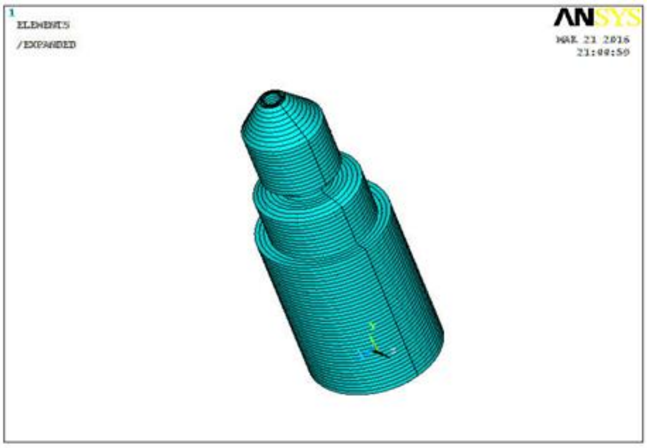

Fig.3.3 3D meshed model of the nozzle

Boundary Conditions for Structural analysis:

Internal pressure load of 80 bar is applied on the inner surface. i.e. on the inner lines of the nozzle part. The bottom of the nozzle part is fixed in all dof.

4. Results and Discussion:

From the analysis, the deflection of the nozzle is calculated and plotted. The maximum displacement of the nozzle as shown in the below figures.

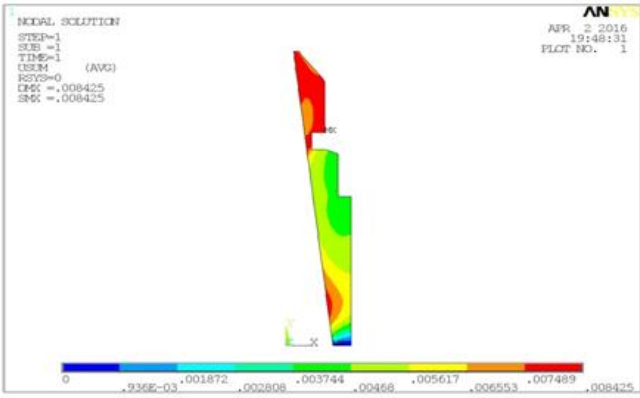

Fig.4.1. displacement vector sum of the nozzle on the section.

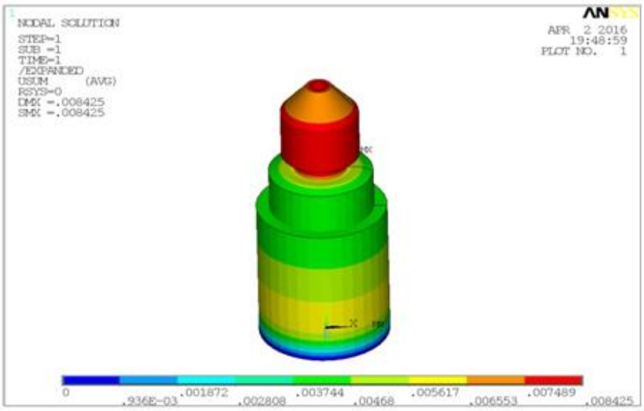

Fig.4.2. displacement vector sum of the nozzle.

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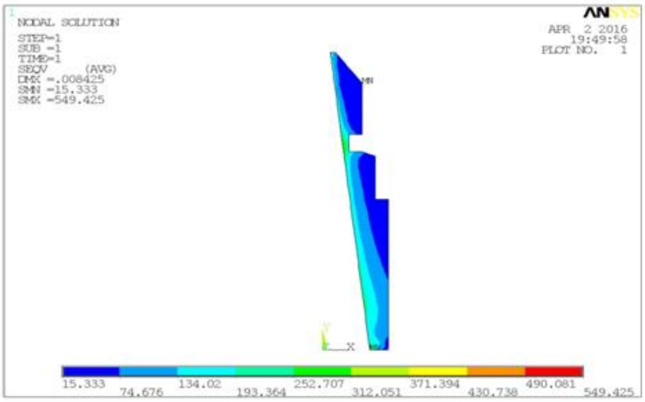

Fig.4.3 Von Mises stresses plot of the nozzle section.

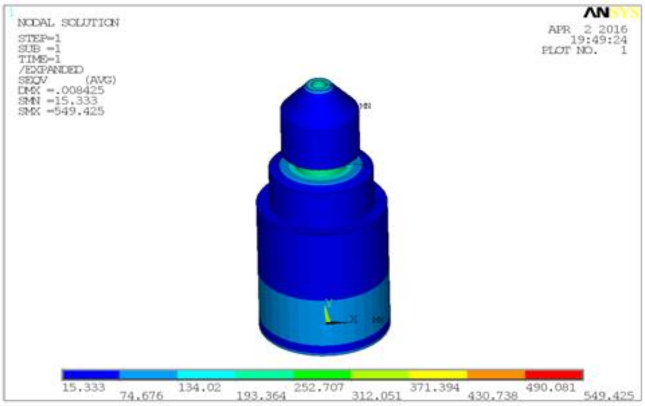

Fig.4.4 Von Mises stress plot of the nozzle.

The Von Mises stress in the nozzle is 134 N/mm^2 as shown along the path (membrane + bending). The stresses are plotted along the path to identify whether the stresses are real or spurious stresses. From the above plot the maximum stress is 549 N/mm^2, which is a spurious stress and can be ignored. However with the path operation the stress is well below the yield strength (180 N/mm^2) of the material and below the design stress of 0.67x335 = 224 N/mm^2.

Linearized Stresses of Nozzle:

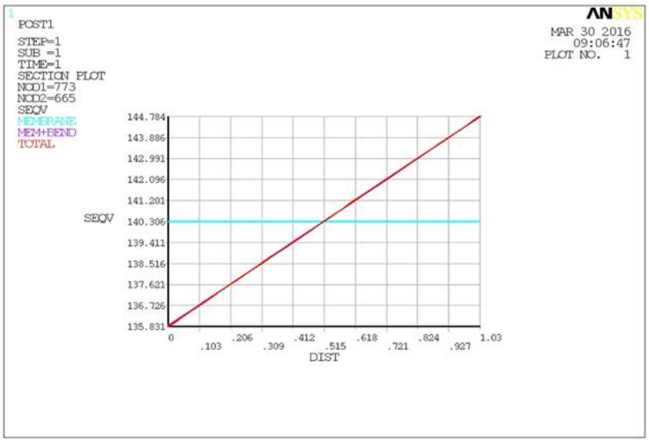

Fig. linearized stresses of nozzle.

5. Operation on CNC lathe:

Fig.5.1 Final Object

7. Conclusions:

Until recently the primary analysis method had been hand calculations and empirical curves. New computer advances have made finite element analysis (FEA) a practical tool in the study of behaviour of designs, especially in determining deflections.In this project Ansys software was used to do the analysis on the nozzle.In the project the deflections of the nozzlewere calculated by performing structural analysis and found the deflections as 0.06mm and maximum stress in the parts are and 134.56 N/mm^2 which is less than the yield strength of the meterial ie., 180 N/mm^2 and hence the design is safe.

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