Proceedings International Seminar of Aerospace Science and Technology 17th SIPTEKGAN -2013, 12: 83-89

COMPARATIVE ANALYSISOF STRUCTURE RX 3228NOZZLE WITH THE RX 3240 NOZZLE MATERIAL S45C

Ediwan, Agus Budi Jatmiko
Rocket Technology Centre, National Institute of Aeronautics and Space - LAPAN
ediwan.ok20@yahoo.com

Abstract

In May 2008 was conducted static test of RX 3228 rocket and in July 2013 the static test done again RX 3240 with different nozzle form and dimensions based on ease of graphit contour manufacture. Although the results of the second static test nozzle has done pretty well, but still needed design improvementfor a lighter and easier installation process.

Assumptions made on both the nozzle is the same, where the side entrance, just accept it as part of the pressure load is protected with graphite, while divergent part that no graphite, just accept the burden of temperature, so that the analysis conducted by the adjusted load received the nozzle structure. Obtained from the simulation of the load stress occurs in the second part of the nozzle with a safety factor of convergent part due to the influence of pressure loads 4 in 2008 and safety factor 3.5 in 2013, while the diverging section that receives factor of safety with thermal loads 1.7 RX 3228 in 2008 and 1.1 for 2013 RX3240 , so that the largest stress corresponding dimensions made rocket was due to the divergent part of the effect of temperatures

***Key Word** : Rocket, Nozzle, static*

Nomenclature

V	:stress	
W	: strain	
M	: modulus elasticity	
L	: length	
α	: coefisient of thermal Expansion	

Subscripts

0	: initial
SF	: safety factor

1. Introduction

In a draft , it takes experience to determine the most critical parts of a structure . In order to produce the structure as designed requires skills in various fields and the availability of supporting infrastructure , such as the selection of appropriate materials and manufacturing process is easily done by experienced technicians and inexperienced , and designing with a skilled computer simulations .

Major obstacles that are often encountered in the development of rocket motors generally are material limitations in accordance with the criteria of the design optimization of the desired structure .

Rocket motor nozzle is one of the components of a rocket motor that functions in addition to generating speed and rocket motor thrust , the nozzle should be able to withstand the pressure and temperature of the combustion gases in the rocket motor tube , so that the nozzle structure should have a pretty good safety factor

In the analysis powerof rocket motor nozzle structure, will be done with the help of software based on finite element . Analysis will include stress caused by the pressure and temperature of combustion. For part with graphite, analyzes were performed only on pressure, whereas the effect of temperature is only in the diverging part which doesn't protected by graphite.

Because a rocket can only be used once , then to do the research required considerable structural materials , from the early stages of design optimization has been carried out with the intention of reducing production costs and shorten the manufacturing time . The structure should be strong and lightweight, all dimensions and spesifications have been expected from the start , as diameter, thickness, materials used and easily obtainable according to the strength required for the structure of the rocket.

To meet the conditions above ,the design of rocket motor nozzle should be planned using the structure software. Design by using the software aims to speed up the the designs with the simulation, and images can be analyzed quickly and easily . The image can also be read by other software , such as Autocad to be modified again if the dimensions that have been made are still not safe, for example by reinforcing or extending graphite.

2. Nozzle Charge and Dimension

Load generated by the combustion nozzle structure in the combustion chamber such as pressure and temperature. Each metal will expand due to temperature effect, which the magnitude is various depends of the thickness, material used andthe temperature. materials that are not resistant to temperature will be covered by a thermal or material which more resistantto temperature, As will be discussed later, the rocket motor nozzle with graphite protection.

Function of tube or pipe will be safe and reliable when the work load can be analyzed. Load comes from the combustion of fuel in the form of heat and pressure. To reduce the weight of the structure of the pipe or tube, then certain parts had to be modified. One part that will be modified is the optimum thickness and good shape.

Rocket motor nozzle geometry is analyzed in diameter 320 mmasfig2.1 and table 2.1..Nozzle materialiscarbon steel type S45C with the following specifications,frommodulus of elasticity (E), density (ρ),Voisson ratio(v) andThe maximum tensile strength of materials (σ_{ult}) (Ediwan, 2008)

$E = 2.1 x 10^6$ kg/cm^2
v = 0.25(Voisson ratio)
$\rho = 7.8 x 10^{-3}$ kg/cm^3
$\sigma_{ult} = 6000$ kg/cm^2

The shape and dimensions of the nozzle RX-3240 on static test in 2013, can be seen in Fig. 1 below :

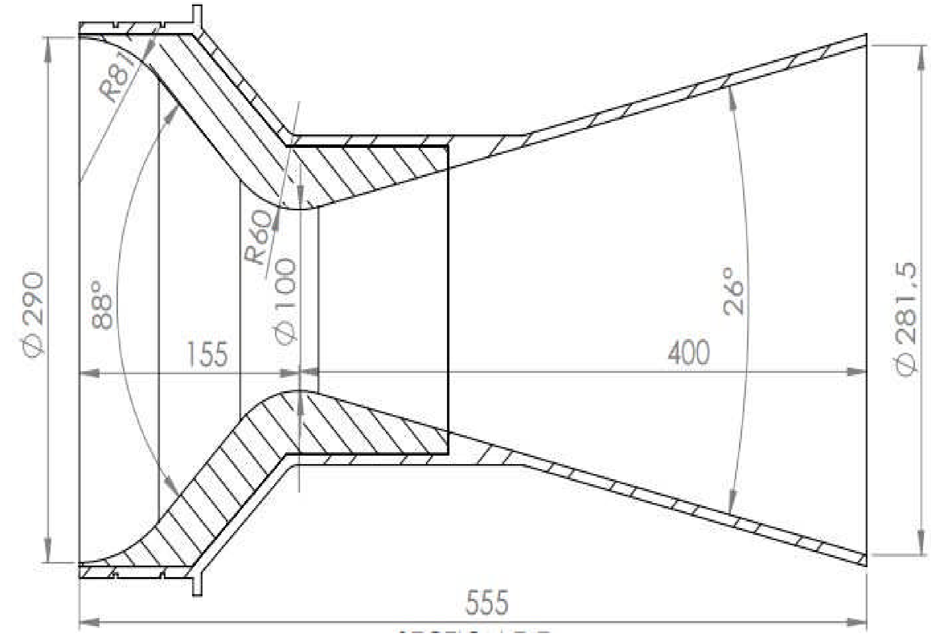


Fig. 1.The dimension of the nozzle RX-3240 in 2013

Table 1. Differences RX 320 in 2008 and 2013

	Rx 320 in 2008	RX 320 in 2013
Tube Diameter (mm)	320	320
Throat Diameter (mm)	90	100
Length Into Throat (mm)	154	155
Total Length (mm)	450	555
Propellant mass (kg)	250	371

To determine the power structure of the nozzle, by the effect of pressure and temperature. The calculation is done using the pressure and temperature from computer simulation results as Fig. 2and Fig. 3 for Rx 3240 in 2013.

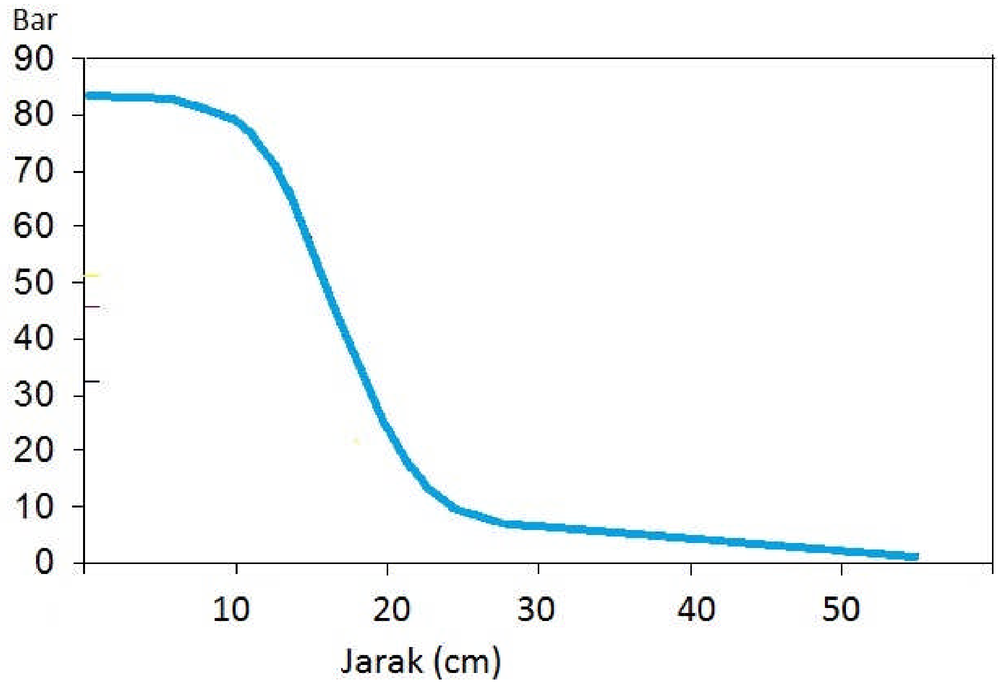


Fig. 2.Nozzle Pressure Simulation

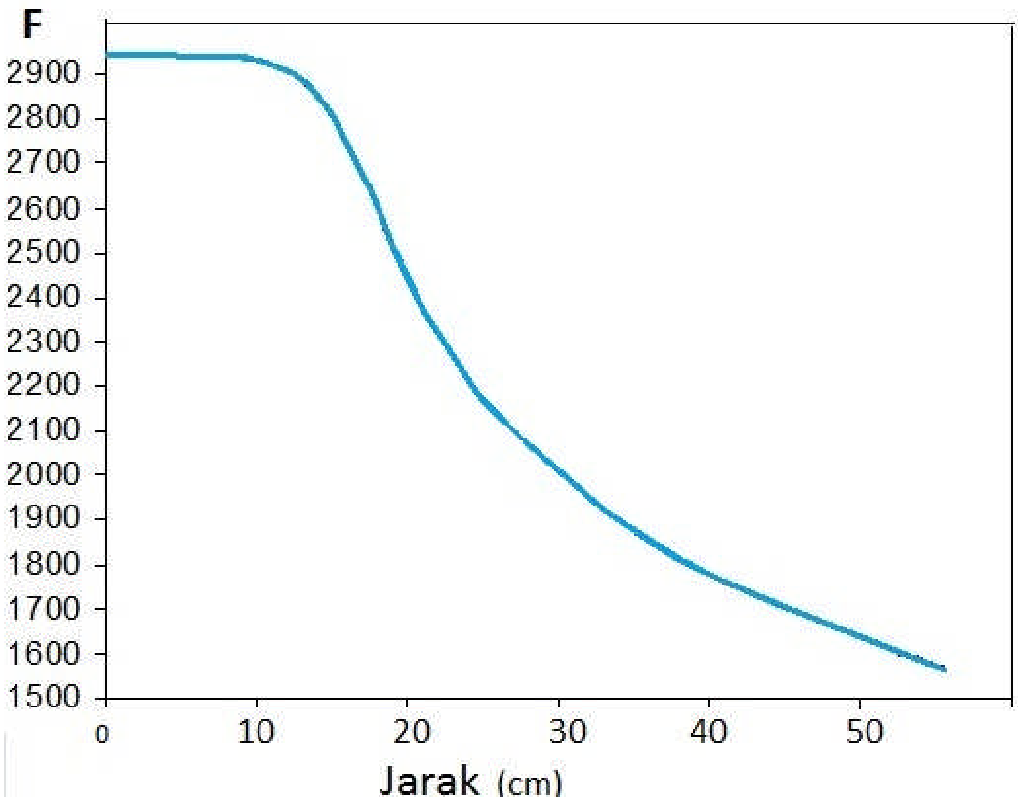
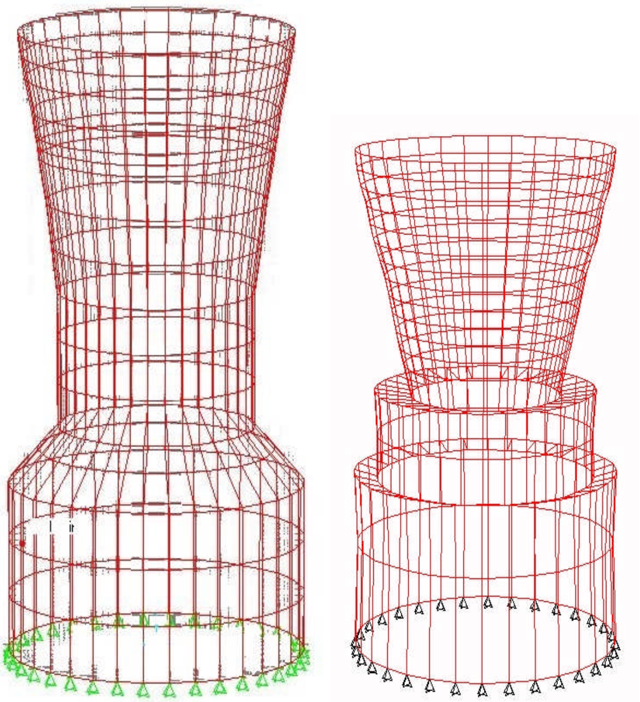


Fig. 3.Nozzle Temperature Simulation

3. Stress Calculation

For ease of calculation, the model is made by makingexit part freely,while the tube clamped as Fig. 4 below :



RX 3240in 2013 RX 3229in 2008

Fig. 4. Modeling results Finite Element Method of Nozzle

In the isotropic elements, for condition of the field stress (*plane stress*), the stress-strain relationship can be expressed as:

$$\sigma = E \, . \, \varepsilon \tag{1}$$

Where σ is stress andε isstrain

For the effect of temperature, the length of the initial term, which is experiencing rising temperatures, can be expressed by:

□L = □ .Lo.□T (2)

Where□□is koefisien of thermal Expantion and Lo is length

Thus the thermal stresses and strains occur, expressed by the following equation:

$$\sigma_t = \frac{\Delta L}{L} .E \tag{3}$$

$$\square = \frac{\Delta L}{L} = \frac{\alpha . Lo . \Delta T}{Lo(1 + \alpha . \Delta T)} \tag{4}$$

.

The equation is used to determine the free-body expansion which is not riveted.The thermal stress caused by thermal expansion can not take place freely on continuous object.

The following are the results of computer simulation for the structure of the nozzle due to the influence of pressure and temperature.

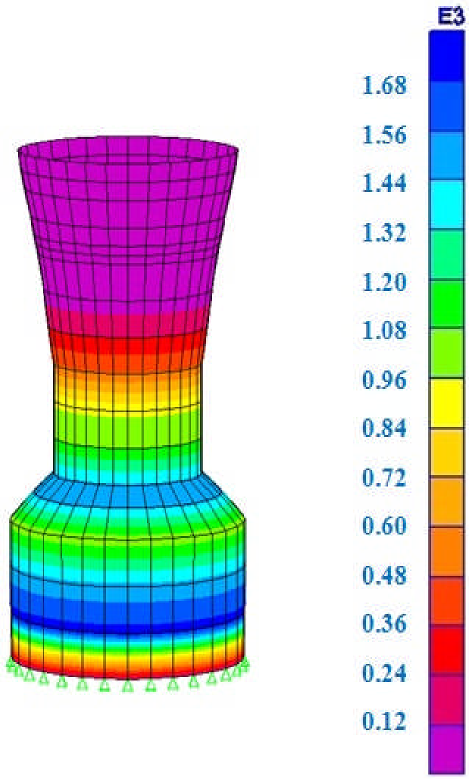


Fig.5.Stress 1680 kg/cm^{2}Pressure effect 80 kgf/cm^2

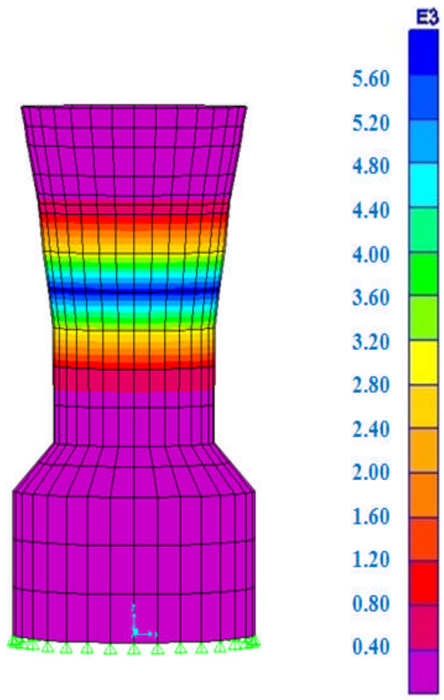


Fig. 6.Stress5600 kg/cm^{2}Pressure effect750 ^{o}F

4. Analysis of Simulation

The result ofFig. 5maximum stress is 1680 kg/cm^{2}caused by the influence of pressure P=80 kg/cm^{2}there are blue areas on theentrance side ofnozzle structureand produces safety factor 3.5, for the full calculation is as follows

For the effect of pressure :

$$SF = \frac{6000}{1680} = 3.5$$

While under the influence of temperature in Fig. 6biggest stressis in the region near the tip of graphite, stress is5600 kg/cm^2, So the value of the safety factor is 1.1 due to the effect of temperature. For the full calculation is as follows

For the effect of temperature :

$$SF = \frac{6000}{5600} = 1.1$$

From the calculation ,nozzle RX-320 is still fairly safe due to the influence of pressure and temperature that occur during static rocket test and for data comparison results can be seen in Table 4. Because the rocket structure used only once, then the safety factor rockets should be greater or equal to 1[2)]

Table 4. Differences Safety Factor and Static Testing Results

	Rx 3228	Rx 3240
Max Pressure (Bar)	70	80
Truss (Ton)	4.5	5
SF Konvergen	4	3.5
SF Divergen	1.7	1.1

5. Conclusions

From the analysis for rocket motor nozzle RX-320 with steel S45C , static test results in July 2013 compared to the 2008 results of the static test can be drawn some conclusions as follows::

- Calculation results due to the effect of pressure on the convergence, factor of safety is 3.5 for the static test in 2013and safety factor is 4 for the static test in 2008 assuming different pressure and both ignore the temperature influence because the converging section coated with graphite.
- Calculation results due to the influence of temperature on the divergent, factor of safety is 1. for the static test in 2013 safety factor is 1.7 for the static test in 2008 with the same assumptions that ignore the influence of pressure because the pressure is quite small in diverging section.
- From the two points above it can be concluded that it is generally the effect of temperature is the most critical part that required more in-depth analysis is necessary to test directly the stress and strain during the static test using strains gage in divergent area.
- In designing the shape of the nozzle structure will affect the shape of the graphite, better use a form which facilitates the manufacture graphite and manufacture time will be faster.

References

1) Ediwan,*Analisis Struktur Nosel RX 320 Dengan BahanS45C*, Jurnal Teknologi Dirgantara, Vol 6, No.2 Desember 2008, LAPAN, Hal 76-82
2) L.H Abraham,*Structural Design of Missiles and SpaceCraft,* McGraw-Hill, New York, 1967
3) Y. C. PAO, *A First Course in Finite Element Analysis*. Allyn and Bacon, Boston USA, 1986
4) J.P Holman, *Heat Transfer* , McGraw-Hill Book, Inc, New York, 1981
5) Boley And Weiner, *Theory of Thermal Stresses*, John wiley and Son, Singapore, 1982
6) Cook D, *Consepts And Applications of Finite Element Analys*, John Wiley Inc, 1982
7) Alan A, 1984, *Computer-Aided Heat Transfer Analisis*, McGraw-Hill, Tokyo, 1984
8) Morgan, *Numerical Metods in Heat Transfer*, John Willey, 1981
9) E.R Parker,*Material Missiles and SpaceCraft,* University Barkley California, 1967
10) User Manual SAP2000 v7.42. *Structure Analysis Program* Computer and Structure Inc, California University Avenue Berkeley, USA

Discussion

Question

1. Usually for max stress indicator is red, but why in your paper the color is blue? (Agus Bayu Utama, LAPAN)
2. Assuming different pressure, how much different pressure? And what matter if the pressure is the same □ in conclusions(Mabe S, LAPAN)
3. in analysis: the influence..... & in 2008 and safety factor 3,5 in 2013, so how the influence in 2013 and safety factor in 2008, and another sense(Mabe S, LAPAN)

Answer :

1. Color is an image that can be set, but the significance of the number of stress
2. Due to the different dimensions of the nozzle length and a different fuel, then the Pressure is different
3. With different dimensions of the data propulsion and the safety factor is also different