Finite Element Analysis on RCC Pneumatic Actuator Scotch Yoke

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Abstract

Vital efforts are been made to study a Remote Controlled Compact Pneumatic Actuator. Scotch-yoke is an important component whose function is to convert rotary motion to linear motion. The scotch-yoke is subjected to compressive forces and was found to be the component failing consistently in the actuator. Hence it was found necessary to modify the existing design. This paper attempts to perform a design optimization of the scotch-yoke used in the RCC pneumatic actuator using linear static analysis. The results are compared and changes are suggested. The key parameters of interest of deflections & stress distributions in the scotch yoke. The baseline model had deflection of 4.234 mm, 1.9783 mm & 0.0125 mm in the x, y & z directions respectively while the deflections in the optimized model had deflection of 3.943 mm, 2.296mm & 0.006007 mm in the x, y & z directions respectively. The normal stresses in the baseline model 2191 N/mm2, 1439 N/mm2& 681.063 N/mm2 in the x, y & z directions respectively, whereas the normal stresses in the optimized model were 1369 N/mm2, 1392 N/mm2& 521.707 N/mm2 in the x, y & z directions respectively. The von Mises stress in the baseline model was 3643N/mm2 and in the optimized model is 2706 N/mm^2.
Keywords: RCC, IGES, Scotch yoke, Fea, ANSYS

I. INTRODUCTION

Remote Control Compact (RCC) actuators are pneumatic actuators and they are compact with high output torque for their size. They are intended for ON/OFF duty or position control to suit most quarter turn valves. The RCC Pneumatic Actuators are today used within the process industries, food processing industries, marine installation, etc. and are capable of operating even in arduous condition The RCC Actuators work according to the scotch yoke principal which means an increased output torque at the beginning and end of its operation. Due to this quality they are well adopted to the demand of most quarter turn valves with large opening and closing torques.[6]

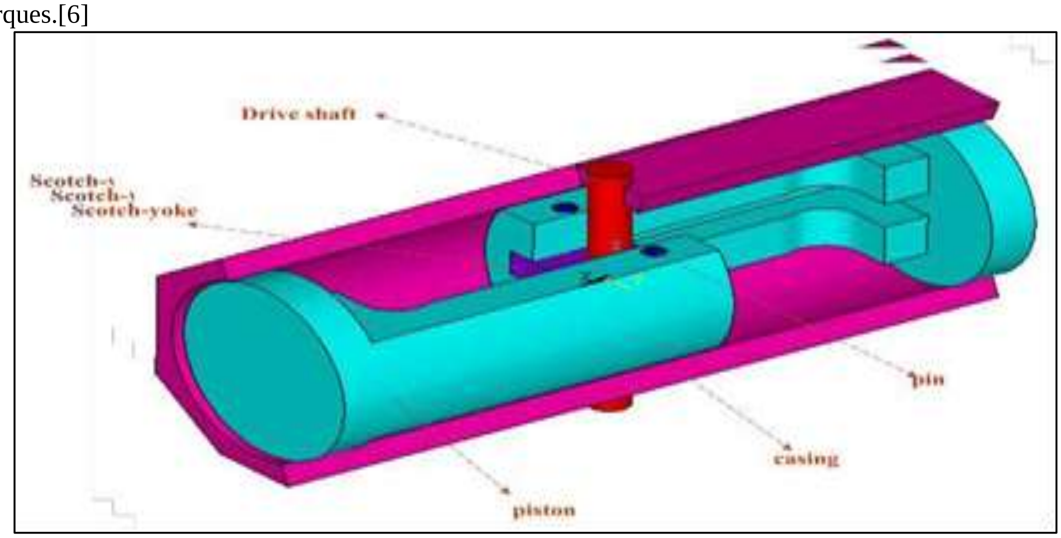

Fig. 1: Parts of the RCC Actuator

A. Cylinder:

it is made of an aluminum alloy. It is extruded, anodized and has good corrosion resistance. It is easy to clean. It acts as a casting for other parts of RCC actuator.

B. Piston:

It is made of aluminum durfondal. Two pistons are used in the RCC actuators which are held by scotch yoke and pin assembly. Piston can move linearly according to the input torque given to the drive shaft. Scotch yoke: this is a very important part in the RCC actuator which is made up of stainless steel. It is hardened with angled slots. Thus the output torque can be given different values depending on how the pistons are mounted in the actuators. During working condition, the scotch yokeis under compression and we are trying to analyze the stress distribution on it.

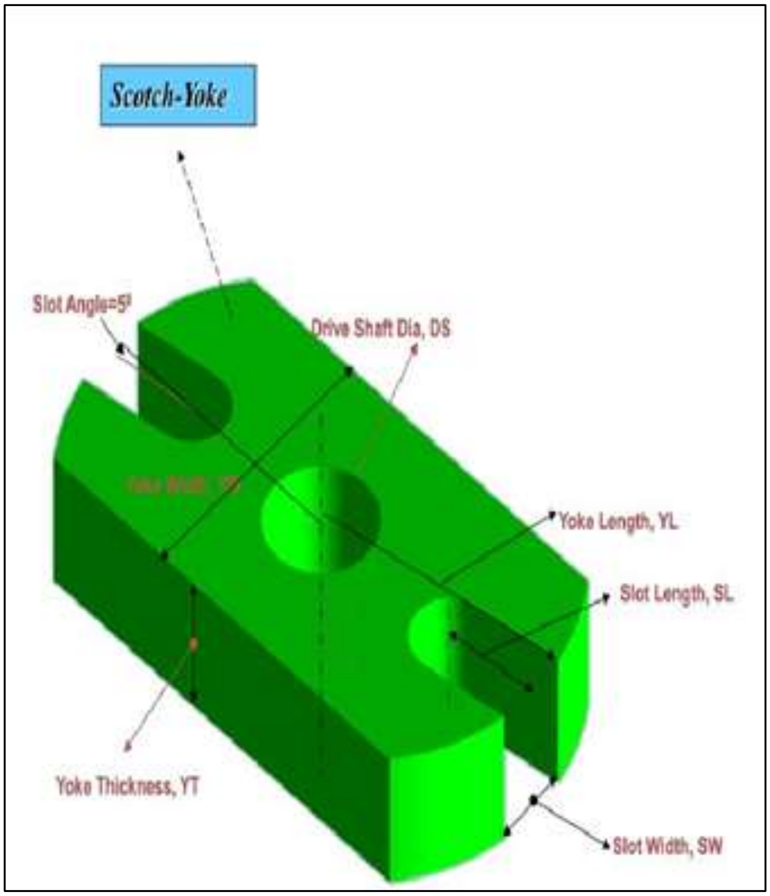

Fig. 2: Scotch yoke dimensional parameters

C. Drive Shaft:
it is also made up of stainless steel which is chemically wicked-plated over its surface. It can also be designed as flats for manual operation. This shaft is inserted into the runner which is made up of acetal plastic. This runner has a low friction and acts as a perfect guide for the piston. The desired torque can be applied through this drive shaft.

D. Pin:
it is made up of steel. Piston and scotch yoke are well connected with the help of the pin. It can be fitted into the hole of the piston. During working condition, the pin is under tension. Support element: it is made up of PTFE material and is carbon filled. It gives support for piston and other assembly. It has a low friction, no metallic contact between and cylinder. Lubrication: RCC actuators are permanently lubricated and additional lubrication is normally not required. Operating medium: the air or inert gas to be used must be filtered. If there is a risk of frecting, the air should be dried. Installation & Adjustments: actuator can be mounted in various positions i.e. vertical or horizontal. When mounting on a valve, it is important that the actuator drive shaft and valve stem are centered. After mounting, the adjustment can be made by loosening the lock nut on the end plates and turning the screw clockwise for reduced and anticlockwise for increased rotary motion.

II. OBJECTIVES

To assess and evaluate the stress & deflection characteristics of the scotch yoke under the specified maximum surface loading condition. To study the stress distribution in the baseline and the optimized model. To find and plot the stress and displacement contours of the scotch yoke for the baseline and optimized model under the maximum surface loading condition. Linear static analysis is to be performed in order to find the stress & displacements. To perform the structural design optimization by comparing the results of the baseline model with the different iterations. Study of further iterations to improve or reduce deflections by providing extra thickness to the scotch yoke.

III. PROBLEM DEFINITION

The scotch yoke plays an important role in modern RCC pneumatic actuators. An attempt is made to design a perfect virtual prototype of a scotch yoke. The problem undertaken here involves the analysis of the scotch yoke under maximum surface loading condition and thereby optimizing the scotch yoke design by putting real time boundary conditions.

The test aims at studying the stress pattern of the scotch of RCC pneumatic actuators. The required results of interest are

– Deflection characteristics.
– Stress distribution
– Design optimization

The same results are repeated for different iterations.

IV. LOADS AND BOUNDARY CONDITIONS

The scotch yoke is constrained in a similar way as it is constrained in real time boundary conditions in all degrees of freedom as given by the client. Material properties supplied by the client are Young's Modulus E=210×103 N/mm2. The poisson's ratio is 0.3333.Permissible yield limit is 256N/mm2, Permissible Deflection is 5.00mm, Permissible Design Stress is 130N/mm2, And Factor of Safety 6.25(as per customer design std.)The two pistons are rigidly fixed at the ends so that there should not be any buckling during the analysis. The driving shaft, shear pin and scotch yoke are constrained in all degrees of freedom. A maximum surface load of 55N/mm2 is applied on both faces of the piston.[6]

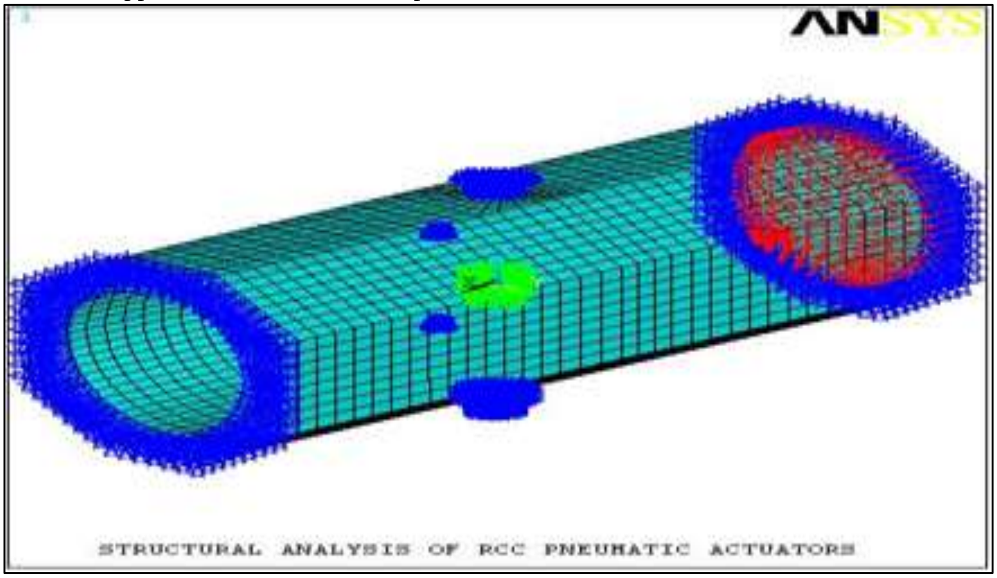

Fig. 3: Loads & boundary condition plot

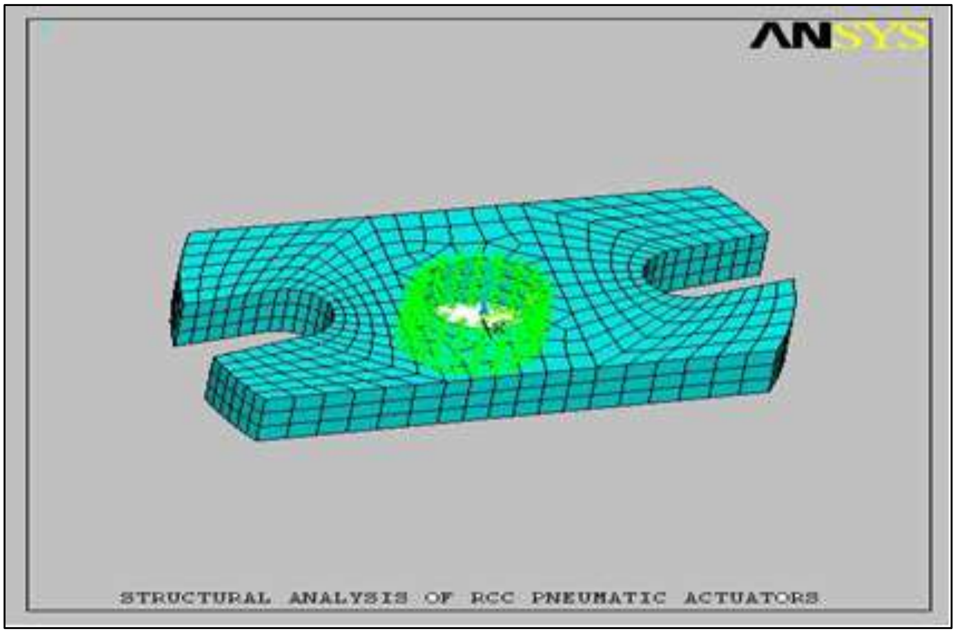

Fig. 4: Meshing

V. RESULT ANALYSIS

Table – 1
Comparison table

Iterations	*Deflections in x-axis in mm*	*Deflections in y-axis in mm*	*Deflections in z-axis in mm*	*Von-mises Stress N/mm²*
1	*4.234*	*1.97*	*0.012*	*3046*
2	*3.921*	*1.99*	*.009*	*3294*
3	*3.836*	*2.03*	*.008*	*2983*
4	*3.759*	*2.197*	*.007*	*2837*
5	*3.943*	*2.29*	*.006*	*2706*
6	*3.923*	*2.31*	*.005*	*2756*
7	*3.810*	*2.00*	*.004*	*2777*

Table – 2
Scotch yoke dimensional changes with each iteration.

Iterations	*Yoke diameter*		*Slot design*		*Drive shaft*
	width	*thickness*	*width*	*angle*	*diameter*
1	*18*	*4.66*	*5*	*4*	*8*
2	*20*	*6*	*5*	*5*	*8*
3	*20*	*6*	*5*	*5*	*8.5*
4	*21*	*7*	*5.86*	*5*	*8.7*
5	*21*	*7*	*5.86*	*5*	*8.7*
6	*22*	*8*	*6*	*5*	*8.8*
7	*22*	*8*	*6*	*5*	*8.8*

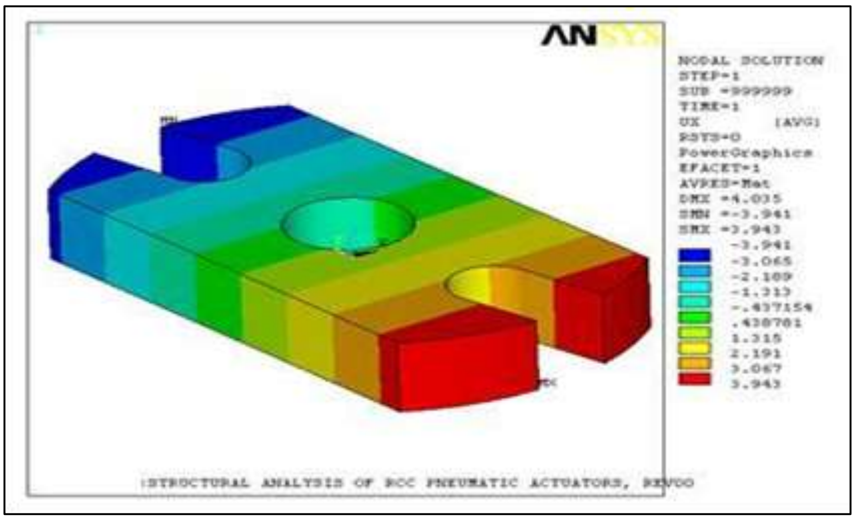

Fig. 5: Deflection in x direction of optimized scotch yoke

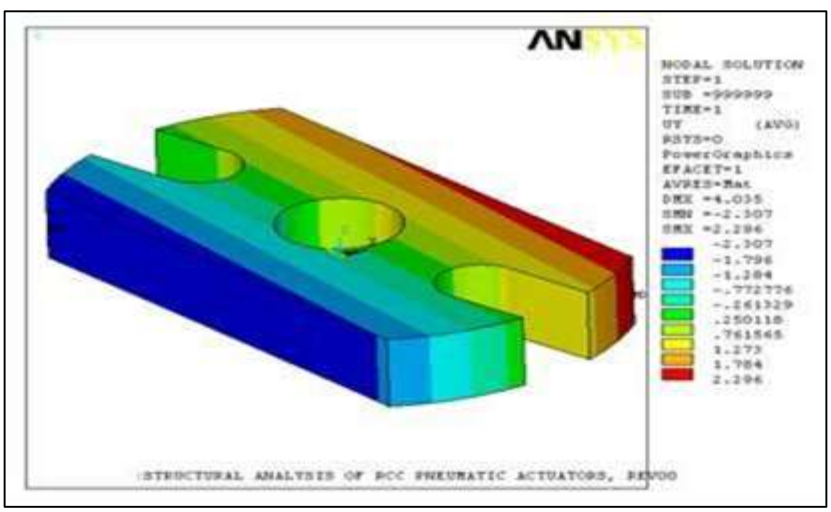

Fig. 6: Deflection in y direction of optimized scotch yoke

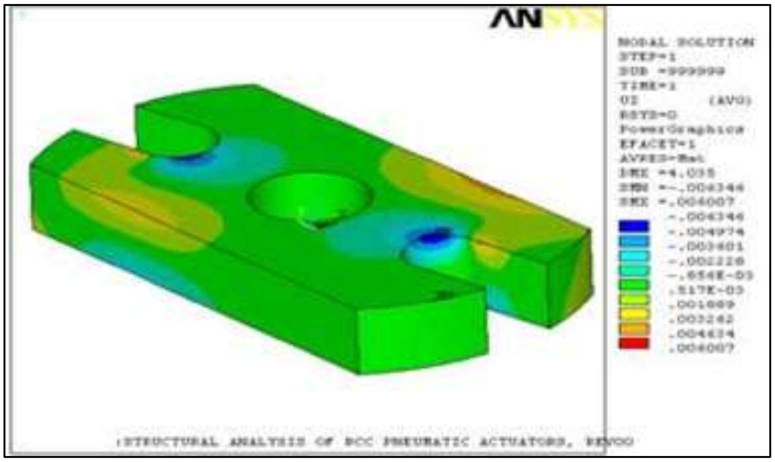

Fig. 7: Deflection in z direction of optimized scotch yoke

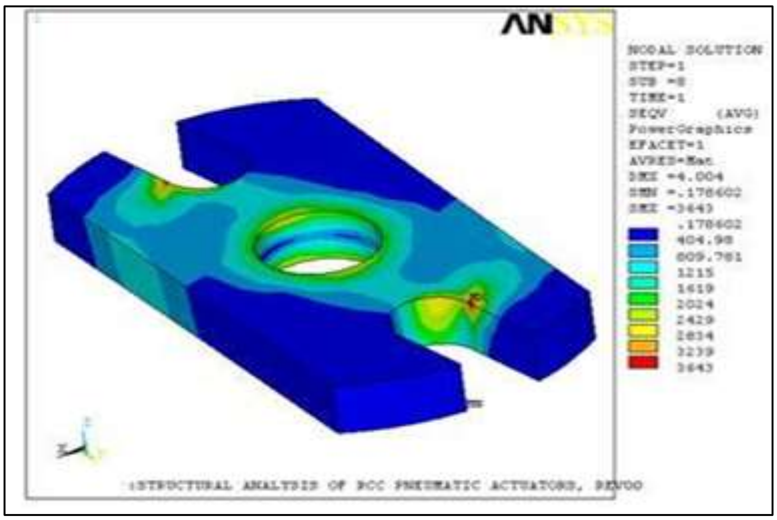

Fig. 8: vonMises stress of baseline scotch yoke

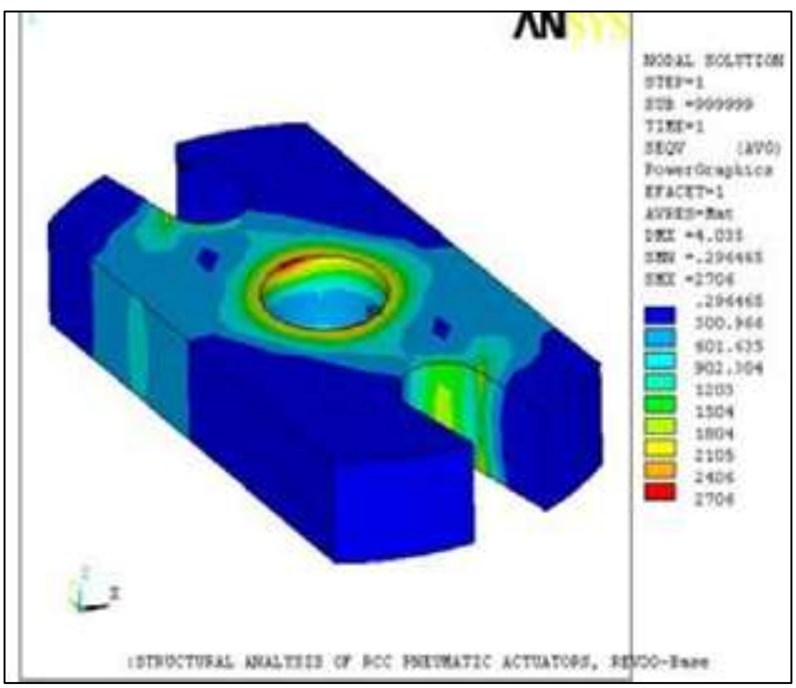

Fig. 9: vonMises stress of optimized scotch yoke

VI. CONCLUSION

- The stress and deflections were reduced by changing the dimensions.
- The stress concentration was reduced at the region on the scotch yoke in contact with the shear pin by providing extra thickness to the scotch yoke.
- The structural analysis of the baseline model was found to be unsafe as their stress and deflections were higher than the permissible values.
- The deflection in the baseline model of the scotch yoke was higher than the permissible value. Even after performing 7 iterations, the value of the iteration could not be reduced to satisfactory levels. But, our main concern was to reduce the stresses. The crucial reason for the failure of the scotch yoke was higher stress levels. Hence it was felt necessary to consider iteration no. 5 as the optimized one. This conclusion has been achieved after compromising with the deflection. Hence iteration no. 7 was found to be satisfactory.
- After analyzing the results of the baseline model and various iterations, it was observed that the scotch yoke is failing at the centre and pin region.
- The improvements are done by providing extra thickness to the scotch yoke and it is shown in the iteration no. 7 where we can see the reduced deflections in all the three axis x ,y, and z axis

REFERENCES

[1] Ansys Technical Overview, Canonsburg, PA, copyright 1997, SAS IP Inc.
[2] R.D. Cook, Concepts & Applications of Finite Element Analysis, 2nd edition, John Wiley & Sons Inc., NY, 1981.
[3] C.S Desai & J.F. Able, Introduction to Finite Element Methods, New Delhi, CBS Publishers & Distributors, 1987
[4] K.J. Bathe, Procedures in Engineering Analysis.
[5] Nitin S. Gokhale, Sanjay S. Deshpande, Sanjeev V. Bedekar, Anand N. Thite, Practical Finite Element Analysis, First Edition, Finite to Infinite, Pune, India, 2008.
[6] Suresh S bujari, Karthik A.S, Structural Analysis of RCC Pneumatic Actuator Scotch Yoke, International journal for research & development in technology,Volume-5,Issue-5,May-16,ISSN(O):2349-3585