Flow and Strength Analysis of Sirocco Fan Using Contra Rotating Rotors

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ABSTRACT

A sirocco fan using contra-rotating rotors in which an inner rotor is settled inside the sirocco fan rotor and each rotor rotates in an opposite direction was proposed for the purpose of getting the higher pressure and making the structure of a sirocco fan more compact. In this thesis, a sirocco fan is designed and modeled in Pro/Engineer. Two models of single and contra rotating types are considered. At present number of blades is 50. In this thesis, the number of blades is changed to 35 and 55. By reducing the number of blades the weight of the fan reduces. And increasing the number of blades the efficiency of the fan increases. The present study is aimed to find the advantage in both the design changes. Structural analysis is done on all the models to verify the strength of the blades.

Keywords - *Sirocco fan, centrifugal fan, PRO-E, structural analysis of fan, contra rotating fan*

1. INTRODUCTION

Fans are widely used in industrial and commercial applications from shop ventilation to material handling, boiler applications to some of the vehicle cooling systems. The performance of the fan system may range from free air to several cfm (cubic feet per min.). Selection of fan system depends on various conditions such as airflow rates, temperature of air, pressures, airstream properties, etc. Although, the fan is usually selected for nontechnical reasons like price, delivery, availability of space, packaging etc. The fan is always analysed by its performance curves which are defined as the plot of developed pressure and power required over a range of fan generated air flow. Also these fan characteristic curves can be used to data like fan bhp for selection of the motor being used. A sirocco fan is a centrifugal fan with a forward curved blade. It is used for low pressure but has a large discharge use. The outlet port of this fan may have a rectangular shape and it is sometimes contained in air conditioning apparatus. Indeed, a forward-curved vane can give large momentum to the fluid, but it cannot make for better efficiency.

Extensive research is made in the field of study of performance of sirocco fan. Tsutomu adachi et.al [1] found experimentally the optimum design of the blade shape is based on the considerations that suitable inlet angle will be 75^0-90^0, outlet angle will be 150^0-160^0. For the runner with inlet angle of 75^0-90^0 and outlet angle of 150^0-160^0, the suitable inclination angle will be 35^0 or so. The proper order in deciding the blade shape is considered to be, first, inlet angle; next, the inclination angle; and then blade outlet angle. The most suitable inclination ratio which is the ratio of blade inclination and blade inlet angle is 0.41. The blade must be as thin as possible. Yui Komon et.al [2] worked and found that all the jags should be set at 0.55 in the first half of the chord length. The last jag should be set on the positive pressure side. The circular arc blade is weak under pressure because the lift is not efficient, and flow separation and turbulence occur downstream of the suction side of the blade. Because the lift of the newly developed fan is efficiently generated by the airfoil, the flow is smooth downstream of the suction surface of the blade. O.P. Singh et.al [3] made the study and concluded that increase in the number of blades increases flow coefficient accompanied by increase in power coefficient. However, difference in the performance (efficiency, flow and power coefficient) tends to decrease at higher pressure coefficient. Hence, fan performance measurement under high pressure coefficient would not provide the true measure of the fan characteristics. Under high pressure coefficient all fan behave similarly. Increase in the number of blades increases the flow coefficient and efficiency due to better flow guidance and reduced losses. V Raghavendra et.al [4] studied that the outlet port of the sirocco fan may have a rectangular shape. Indeed, a forward-curved vane can give large momentum to the fluid, but it cannot make for better efficiency. A sirocco fan using contra-rotating rotors in which an inner rotor is settled inside the sirocco fan rotor and each rotor rotates in an opposite direction was proposed for the purpose of getting higher pressure and making the structure of a sirocco fan more compact. Steady state Structural analysis carried out to verify the strength of blades.

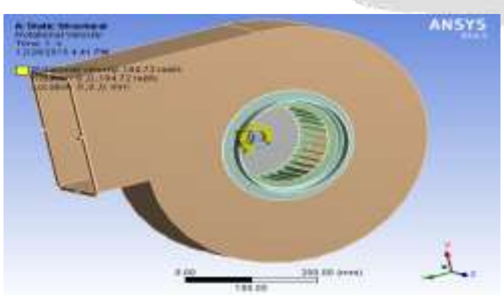
2. PRESENT STUDY

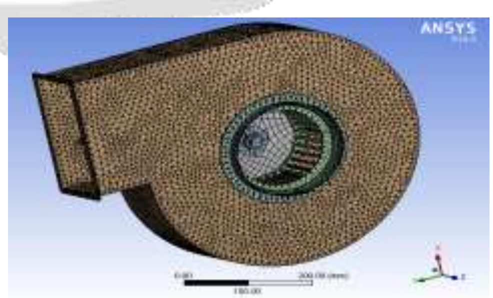
A sirocco fan using contra-rotating rotors in which an inner rotor is settled inside the sirocco fan rotor and each rotor rotates in an opposite direction was proposed for the purpose of getting the higher pressure and making the structure of a sirocco fan more compact. If the high discharge pressure is obtained with the adoption of the contra-rotating rotors, it could be used for various purposes. Pressure coefficient of a sirocco fan with contra-rotating rotors is 2.5 times as high as the conventional sirocco fan and the maximum efficiency point of contra-rotating rotors shifts to larger flow rate than a conventional sirocco fan. On the other hand, it was clarified from the flow measurement results that circumferential velocity component at the outlet of the outer rotor of contra-rotating rotors becomes larger than a conventional one.
In this study, the rotors operate in a duct of diameter D = 380 mm, the ratio θ = NRR/NFR of the rotation rates of the two rotors can be varied, and the axial distance s between the front rotor and the second rotor can be varied in a wide range.

The main results of this study are the maximum of the peak static efficiency of counter-rotating stage CRS is 67 +/- 1% whilst the peak static efficiency of the front rotor alone is 45 +/- 1%. At the design angular velocity ratio $\theta = 0.9$ the overall performances are not significantly affected by a variation of the axial distance in the range s=ε [10;50] mm with s the distance between the trailing edge of the front rotor and the leading edge of the rear rotor. However, at $\theta = 0.9$ the pressure rise is decreased by 5% and the efficiency decreases from 65+/- 1% to 63 +/- 1% when s is increased from 10 to 180 mm. At small axial distances (s < 50mm), the analysis of the power spectral density for wall pressure fluctuations and of the radial profiles of the average velocity confirm that the rear rotor does significantly affect the flow field in the interaction area. Sirocco fans have low efficiency and need empirical designing. The latter results from the fact that the performance curve of Sirocco fans cannot be derived directly from the Euler turbo-machine equation. Therefore, the non dimensional coefficients of Sirocco fans cannot be found on the Cordier curve, but form a small separate band below it . The flow in Sirocco fans is mostly unsteady, fully three-dimensional, turbulent and shows virtually unavoidable flow separation within the blades and the scroll, even at the best efficiency point. The main design parameters such as blade number, ratio of inlet to outlet diameter etc. For instance, in order to optimize the housing, both the scroll width W and the aperture angle as can be varied. Other parameters including the scroll outlet area have been kept constant.

3. RESULTS:

3.1. STRUCTURAL ANALYSIS OF SIROCCO FAN

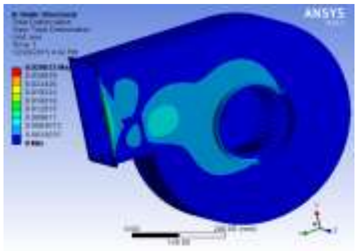
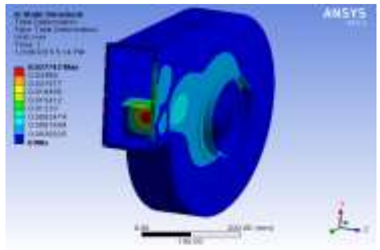
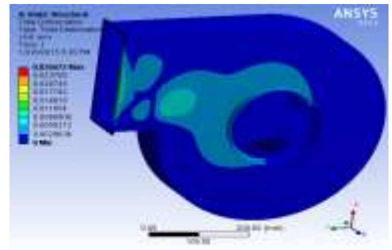




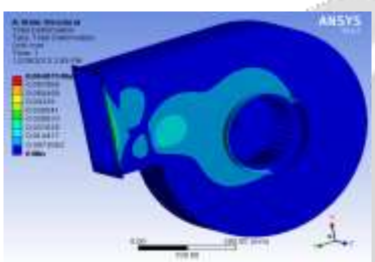
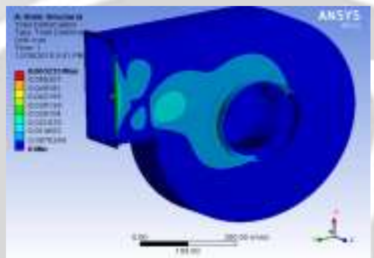
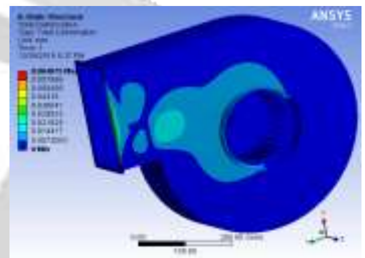
Meshed model

3.1.1. TOTAL DEFORMATION

For 35, 50 and 55-BLADES at 1000 RPM:

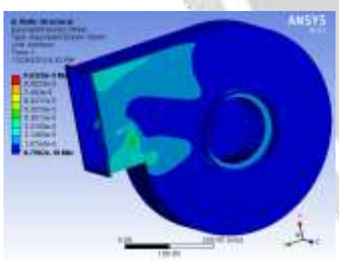
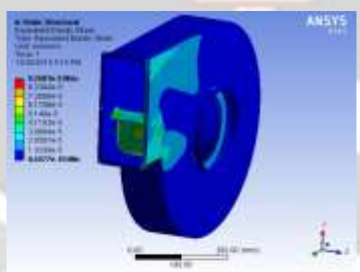
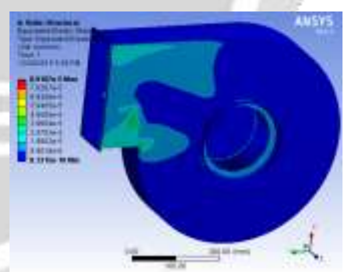




For 35, 50 and 55-BLADES at 1500 RPM:

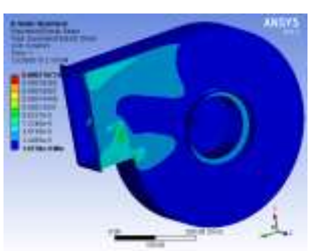
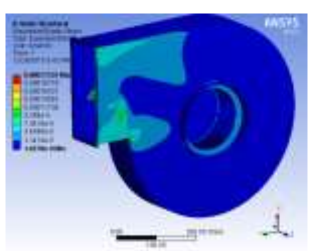
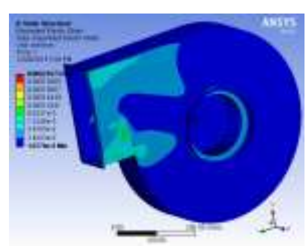




3.1.2 VON-MISES STRAIN

35, 50 and 55-BLADES, 1000 RPM

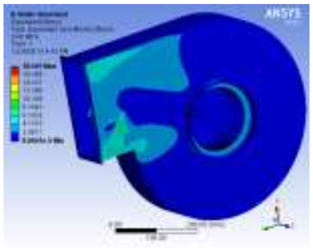
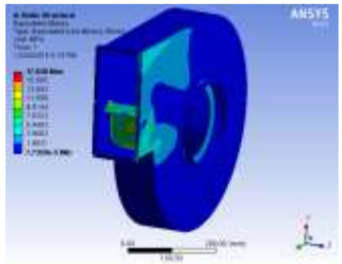
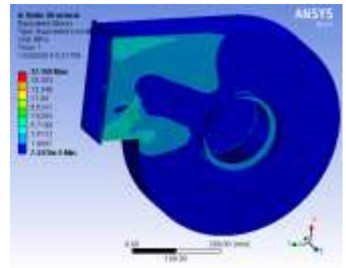




35, 50 and 55-BLADES, 1500 RPM

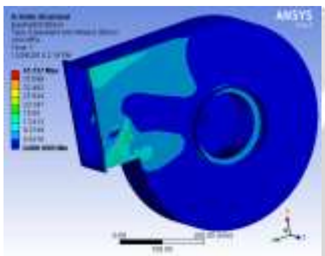
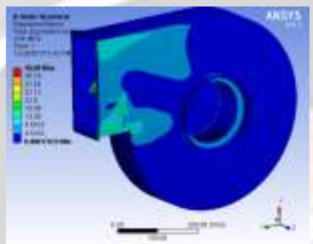
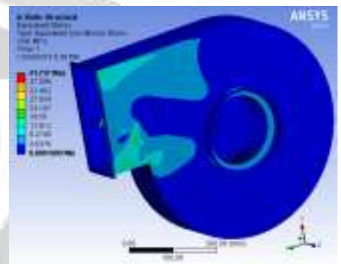




3.1.3. VON-MISES STRESS

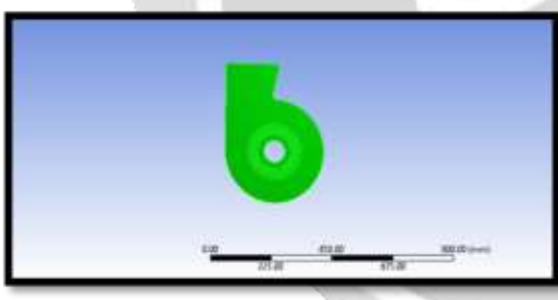
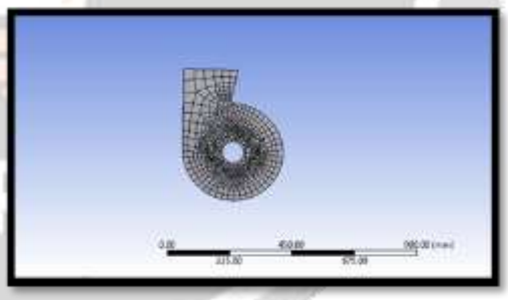
35, 50 and 55-BLADES, 1000 RPM

35, 50 and 55-BLADES, 1500 RPM

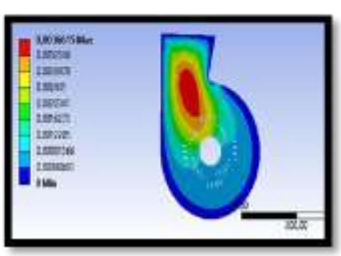
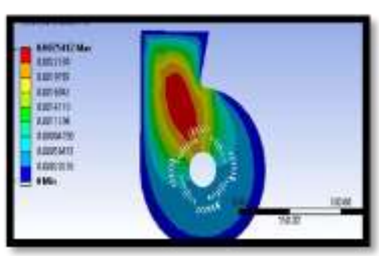
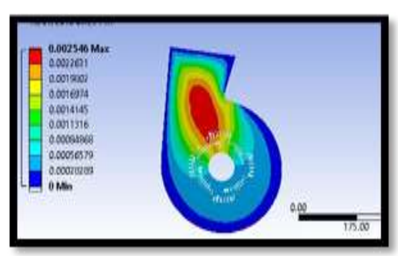
3.2. STRUCTURAL ANALYSIS OF SIROCCO COANTRA ROTATING FAN:

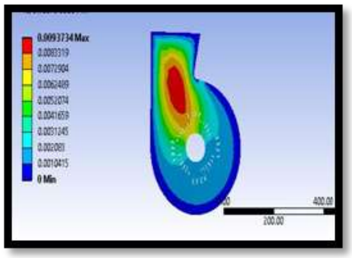
Meshed model

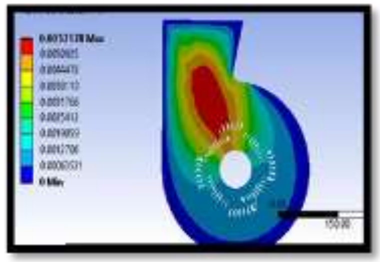
3.2.1. TOTAL DEFORMATION:

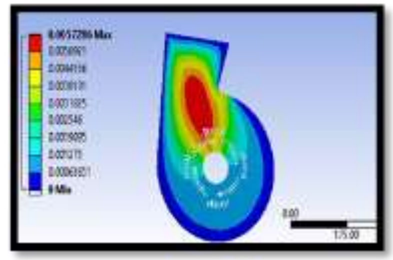
For 35, 50 and 55-BLADES at 1000 RPM:

For 35, 50 and 55-BLADES at 1500 RPM:

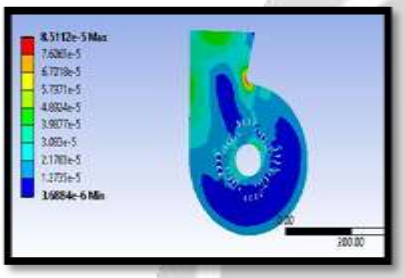


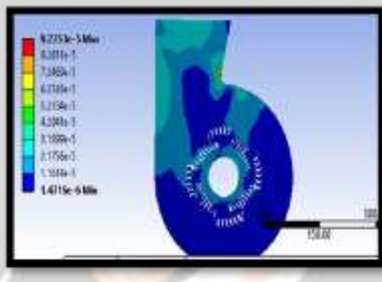


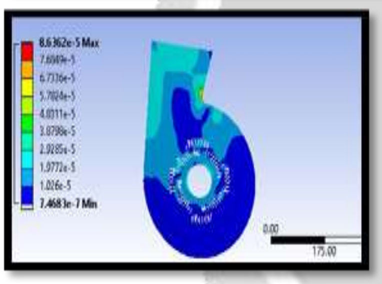


3.2.2. VON-MISES STRAIN:

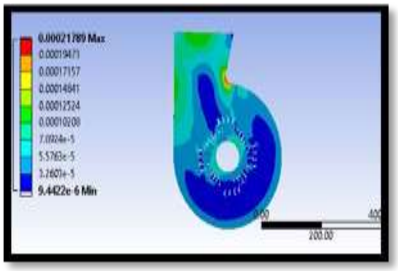
For 35, 50 and 55-BLADES at 1000 RPM:

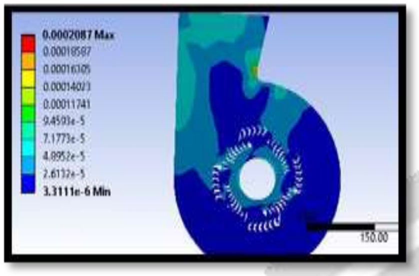


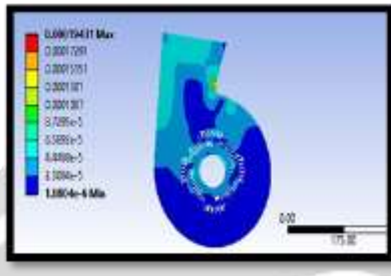




For 35, 50 and 55-BLADES at 1500 RPM:

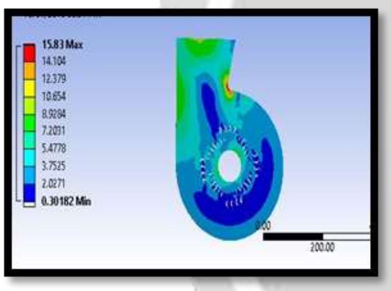


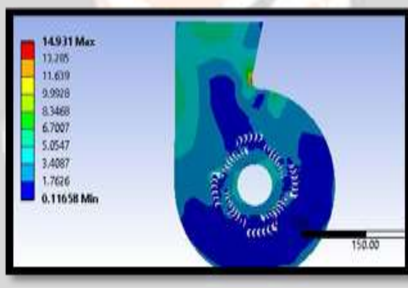


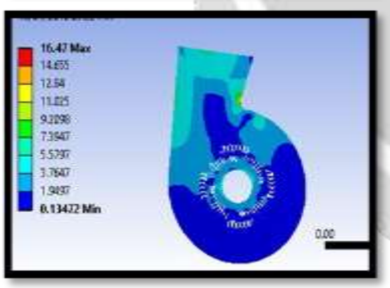


3.2.3. VON-MISES STRESS

For 35, 50 and 55-BLADES at 1000 RPM:







For 35, 50 and 55-BLADES at 1500 RPM:

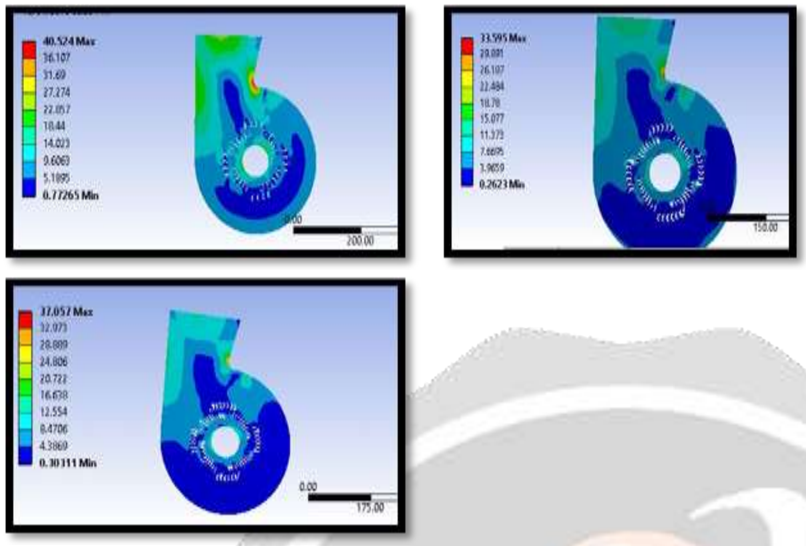


Table -1: Structural analysis of a Sirocco fan,- Steel

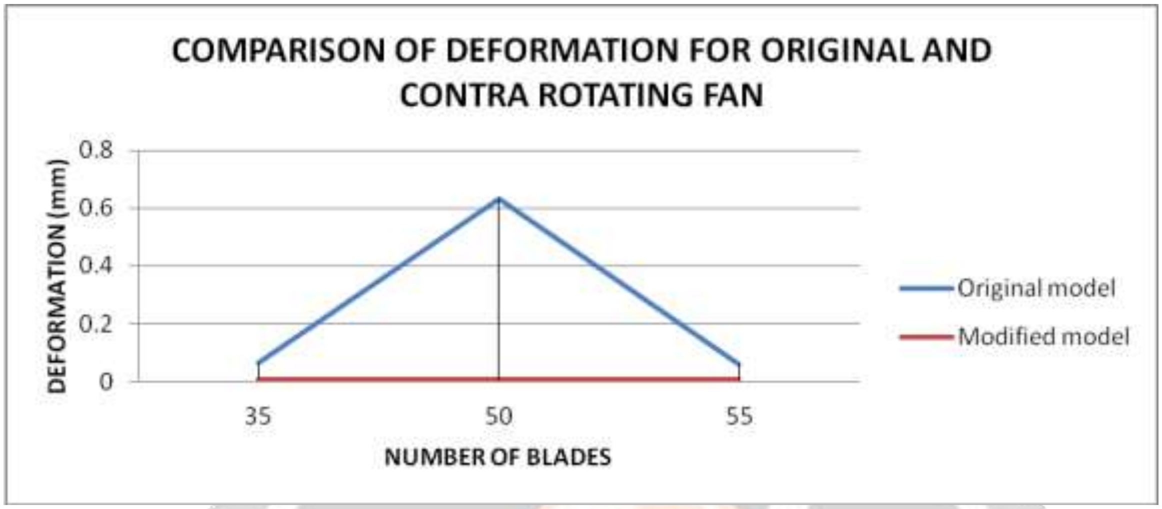
No of blades	35 blades		50 blades		55 blades	
RPM	1000 RPM	1500 RPM	1000 RPM	1500 RPM	1000 RPM	1500 RPM
Deformation	0.028833	0.064875	0.027742	0.063233	0.026672	0.061613
Strain	9.6326e-5	0.00021673	9.2681e-5	0.00021125	8.9107e-5	0.00020584
Stress	18.549	41.737	17.848	40.68	17.159	39.638

Table -2: Structural analysis of a Sirocco contra rotating fan, – Steel

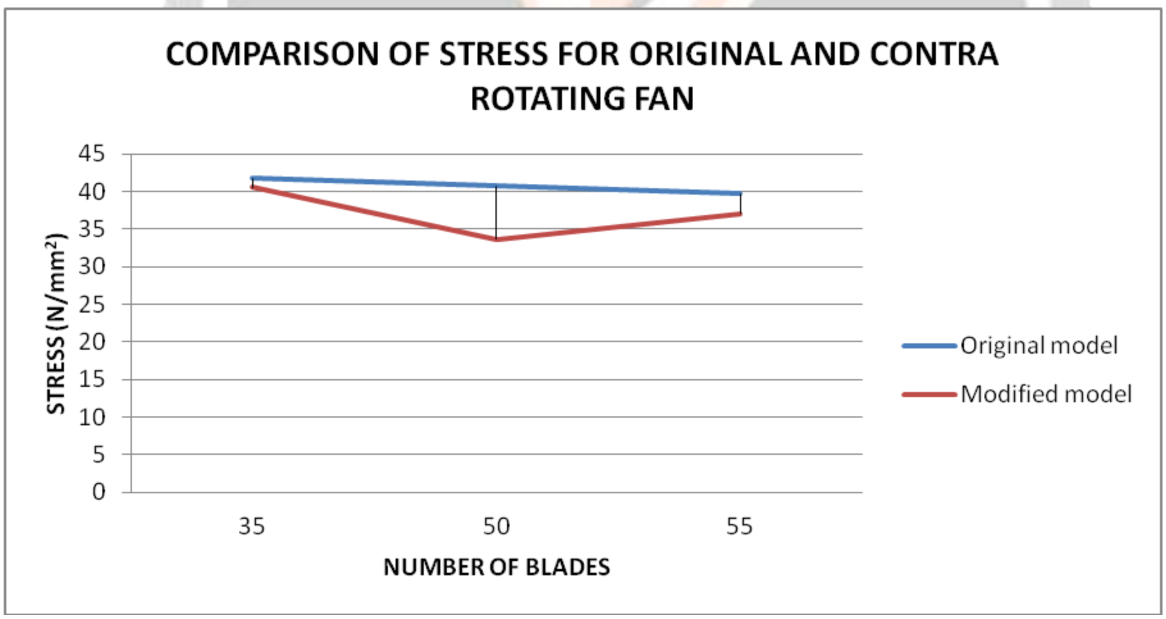
No of blades	35 blades		50 blades		55 blades	
RPM	1000 RPM	1500 RPM	1000 RPM	1500 RPM	1000 RPM	1500 RPM
Deformation	0.0036615	0.0093734	0.0025412	0.0057178	0.002546	0.0057386
Strain	8.5112e-5	0.00021789	9.27535e-5	0.0002087	8.6362e-5	0.00019431
Stress	15.83	40.524	14.931	33.595	16.47	37.057

3.3. COMPARISON GRAPHS FOR ORIGINAL MODEL AND CONTRA ROTATING MODEL

MATERIAL – STEEL



GRAPH 1



GRAPH 2

4. CONCLUSIONS

In this thesis, a sirocco fan is designed and modeled in Pro/Engineer. Two models of single and contra rotating types are considered. Present number of blades is 50. In this thesis, the number of blades is changed to 35 and 55. By reducing the number of blades the weight of the fan reduces. Structural analysis is done on the models to verify the strength of the blades. By observing the analysis results, the stresses are less for contra rotating model than the original model. By increasing number of blades the stresses are slightly decreasing. But the main disadvantage is increase of weight of fan by increasing number of blades.

5. REFERENCES

[1]. Study on the Performance of a Sirocco Fan (Optimum Design of Blade Shape) Tsutomu Adachi,1,3 Naohiro Sugita,1 and Yousuke Yamada, ation
[2]. Development of Sirocco Fan Featuring Dragonfly Wing Characteristics Yui Komon, Masaki Ohtsuka.
[3]. A parametric study of centrifugal fan performance: experiments and numerical simulation O.P. Singh, Rakesh Khilwani, T. Sreenivasulu, M. Kannan
[4]. A Numerical Study and Performance of a Sirocco Fan Using Contra-Rotating Rotors V.Ragavendra Vamsi ,Krishna1 M.Lava Kumar