ijournals International Journal of Software & Hardware Research in Engineering
ISSN No: 2347-4890 Volume 2 Issue 5, May 2014

Theoretical analysis of stress in a centrifugal fan impeller

Author: Dhanapal.T[1], Baskaran.M[2]

PG Scholar, Department of Mechanical Engineering, PSNACET, Dindigul, Tamilnadu[1];
Assistant Professor, Department of Mechanical Engineering, PSNACET, Dindigul, Tamilnadu [2]

ABSTRACT

Theoretical stress analysis of a centrifugal fan impeller has indicated that, the stress factor of impeller components is more complex in the centrifugal fan. The stresses in the impeller components can be reduced, by using the support angle at the back side of the impeller back plate. In this paper, theoretical and finite element approaches have been discussed to study the stresses in the centrifugal fan impeller. The effect of the supporting angle on the stresses has been also investigated and discussed in this paper.

Keywords

Centrifugal fan impeller, support angle, stress.

1. INTRODUCTION AND LITERATURE REVIEW

Centrifugal fans have wide applications in industries for continuous flow of air required for var-ious applications. The impeller of the fan is a highly stressed component. The stresses due to cen-trifugal forces are predominant in fan impellers. The study of stresses in fan impellers is of great interest since past and carried out by many researchers. Haerle [1], Glessner [2], Deutsch [3], Ho [4] and Thurgood [5], used analytical techniques for determination of stresses in fan impeller. Later experimental analysis of fan impeller is carried out by Patton [6], Bell [7] and Ramamurti [8]. The finite element analysis by Bell [7], Bhope [9], Ramamurti [8] and Nabi [10], revealed that, the stress pattern due to centrifugal forces is highly complex in backsheet, shroud and blades of the impeller.

Authors [11] have investigated the effect of stiffening rings on the stress distribution and deflec-tions in the components of impeller by finite element method. Two rings are equispaced at the nose of the blade and one ring is centrally placed at the tail of the blades, between backsheet and shroud. It is observed that, the stresses and deflections have been considerably reduced due to stiffening ring. The effect of location and size of stiffening rings on the stress distribution in centrifugal fan impeller are also studied by the

Authors [12], using the finite element technique. Desai and Badve [13] also used the stiffening rings on the impeller blades and found that, the impeller rotating at 735rpm can be rotated safely at 910rpm, using the stiffening rings. It is necessary to verify the results of finite element analysis, experimentally. Hence, Authors [14] have proposed experimental techniques and setups, for stress analysis of centrifugal fan impeller.

2. MATHEMATICAL MODEL

The backward inclined impeller is considered for the analysis. The impeller is designed and fabricated for the following specifications.

IJSHRE

By using the elementary theory of fan design [15–18], the dimensions of the impeller are deter-mined. The major dimensions are as follows.

The minimum thickness of the impeller components is determined using elementary theory of strength of material [16]. The thickness of back sheet, shroud and blade are considered as 4mm, 2mm and 2mm respectively for fabrication purpose, which are

Discharge	0.5 m^3/s
Static pressure	250 Pa
Total pressure	280 Pa
Speed	1440 rpm

slightly greater than the min-mum required thickness. The impeller is fabricated from mild steel sheets by arc welding process and it is dynamically balanced. The back sheet of the impeller is fixed to the hub. The volute casing has been also designed as per the

Outer diameter of impeller	565 mm
Inner diameter of impeller	380 mm
Width of the impeller	134 mm
No. of blades	08

© 2014, IJOURNALS All Rights Reserved

ijournals International Journal of Software & Hardware Research in Engineering
ISSN No: 2347-4890 Volume 2 Issue 5, May 2014

guidelines given by Bleier [15].

Following types of investigations are carried out for the fan impeller:

1. Stress analysis of impeller with supporting angle using finite element method.

2. Stress analysis of impeller without supporting angle using finite element method.

The various types of analysis carried out and their results are given in forthcoming discussions.

3. STRESS ANALYSIS OF CENTRIFUGAL FAN WITHOUT BACK PLATE SUPPORT ANGLE

The impeller without support angle is analysed for stresses using finite element method. Initially, the self-developed program is used for the analysis. The program is coded in FORTRAN. The program uses triangular shell element with 6 degrees of freedom per node (three translations and rotations about x-, y- and z-axis). This element is based on the classical Kirchh-off s plate theory. The element has bending and membrane capability. The program uses the sky-line solver with variable bandwidth for the solution of equations. The program also has the capability to analyse the cyclic symmetric structures like impellers, by analysing only one repeat-able sector of the whole structure. The program has been tested on known problems. The element used in the program is actually a non-conforming element. Hence, it is seen that, for convergence and acceptable results finer mesh is required. It is also very laborious to create FE model and to interpret the results, which are in the form of large output data.

Hence, it is felt necessary to use the commercial program. Later, the analysis is carried out using processor CSA/NASTRAN with pre–post processor FEMAP. The triangular (TRIA3) and quad-rilateral (QUAD4) plate elements are used for the discritization. These elements are based on the Mindlin s plate theory, which takes into account the effect of transverse shear deformation, which is absent in Kirchhoff s classical theory. These elements give good convergence and better results as compared to earlier element. The impeller is analysed for stresses only due to centrifugal force, which is predominant. The fluid forces are of lesser importance and neglected in comparison with centrifugal forces. The sector of the impeller is discredited with triangular and quadrilateral elements. The impeller is considered as fixed used for fixing the back-sheet to the hub. All degrees of freedoms for the nodes, at these locations are constrained. The FE model of impeller without support angle is shown in Fig. 1. The maximum stresses in the back-sheet, blades and shroud are determined and given in Table 1.

It is seen that, the stresses in the blades are of high magnitude. The stresses can be reduced, by using the support angle at the back side of the impeller back plate. Therefore, various combinations of the support angle on the back plate are tried and their effects are investigated.

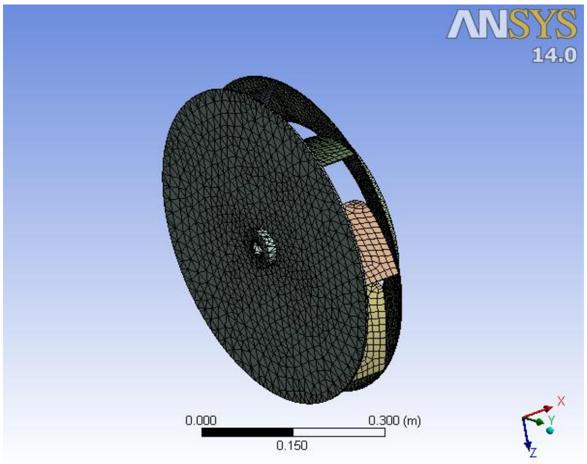

Fig. 1. Impeller without support angle.

The maximum principal stress for the impeller without support angle has been analyzed and it is shown as

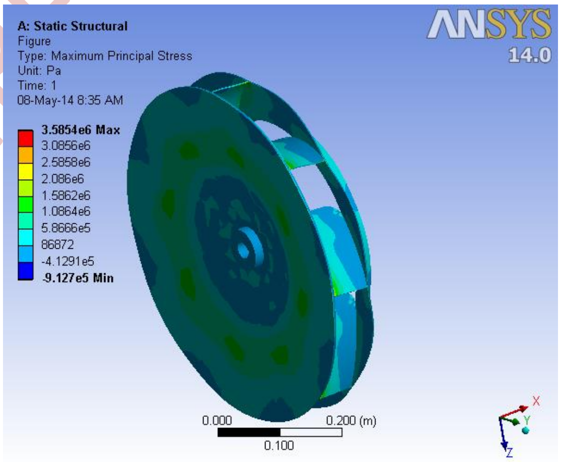

Fig. 2. Maximum principal stress without support angle

The equivalent elastic strain for the impeller without support angle has been analyzed and it is shown as

IJSHRE

© 2014, IJOURNALS All Rights Reserved

ijournals International Journal of Software & Hardware Research in Engineering
ISSN No: 2347-4890 Volume 2 Issue 5, May 2014

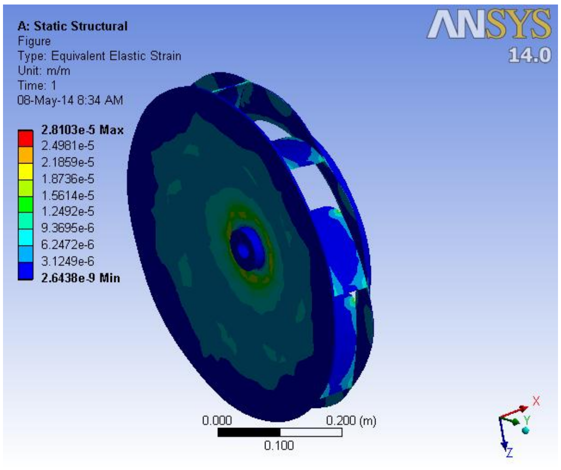

Fig 3. Equivalent elastic strain without support angle

The total deformation for the impeller without support angle has been analyzed and it is shown as

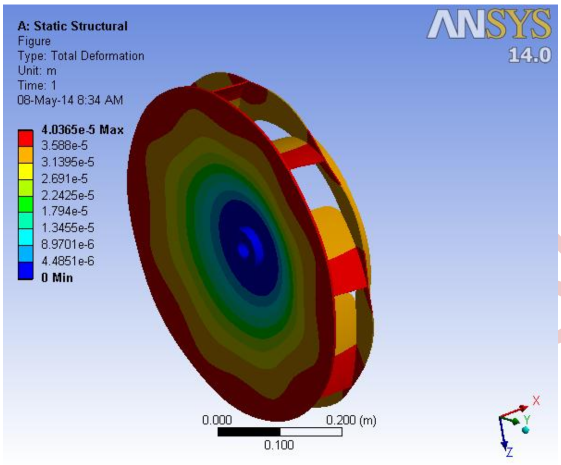

Fig 4. Total deformation without support angle

Table 1 .

Maximum stresses in impeller components without support angle

Forces in impeller components	Min	Max
Maximum principal stress	-9.127e5	3.5854e6
Equivalent elastic strain	2.6438e-9	2.8103e-5
Total deformation	0	4.0365e-5

4. STRESS ANALYSIS OF CENTRIFUGAL FAN WITH BACK PLATE SUPPORT ANGLE

The impeller with support angle is analysed for stresses using finite element method. Initially, the self-developed program is used for the analysis. The program is coded in FORTRAN. The program uses triangular shell element with 6 degrees of freedom per node (three translations and rotations about x-, y- and z-axis). This element is based on the classical Kirchh-off s plate theory. The element has bending and membrane capability. The program uses the sky-line solver with variable bandwidth for the solution of equations. The program also has the capability to analyse the cyclic symmetric structures like impellers, by analysing only one repeat-able sector of the whole structure. The program has been tested on known problems. The element used in the program is actually a non-conforming element. Hence, it is seen that, for convergence and acceptable results finer mesh is required. It is also very laborious to create FE model and to interpret the results, which are in the form of large output data.

Hence, it is felt necessary to use the commercial program. Later, the analysis is carried out using processor CSA/NASTRAN with pre–post processor FEMAP. The triangular (TRIA3) and quad-rilateral (QUAD4) plate elements are used for the discritization. These elements are based on the Mindlin s plate theory, which takes into account the effect of transverse shear deformation, which is

absent in Kirchhoff s classical theory. These elements give good convergence and better results as compared to earlier element. The impeller is analysed for stresses only due to centrifugal force, which is predominant. The fluid forces are of lesser importance and neglected in comparison with centrifugal forces. The sector of the impeller is discredited with triangular and quadrilateral elements. The impeller is considered as fixed used for fixing the back-sheet to the hub. All degrees of freedoms for the nodes, at these locations are constrained. The FE model of impeller without support angle is shown. The maximum stresses in the back-sheet, blades and shroud are determined and given.

It is seen that, the stresses in the blades are of high magnitude. The stresses can be reduced, by using the support angle at the back side of the impeller back plate. Therefore, various combinations of the support angle on the back plate are tried and their effects are investigated.

© 2014, IJOURNALS All Rights Reserved

Forces in impeller components	Min	Max
Equivalent(von-mises) stress	281.05	3.8902e6
Equivalent elastic strain	1.4053e-9	2.3508e-5
Total deformation	0	2.3468e-5

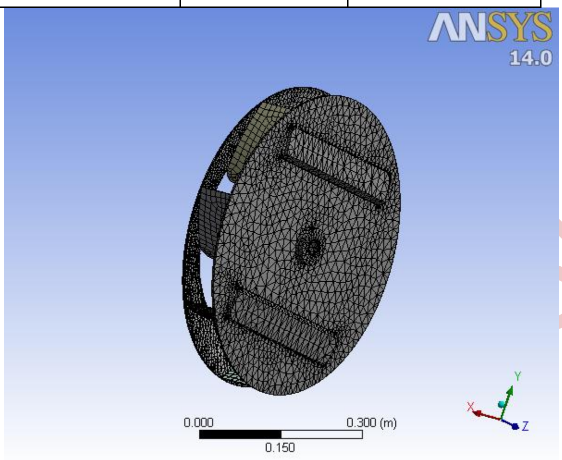

Fig 5. Impeller with spport angle

The equivalent (von-Mises) stress for the impeller with support angle has been analyzed and it is shown as

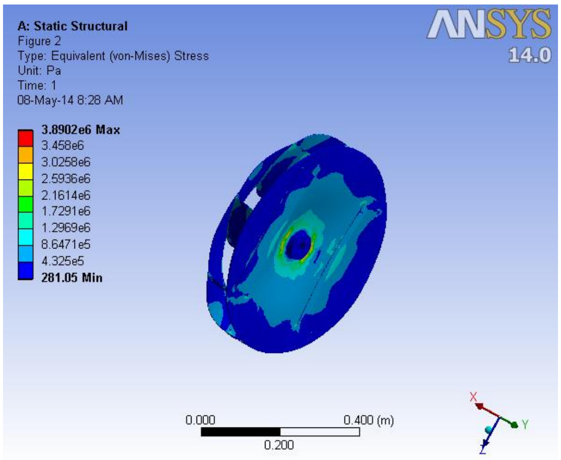

Fig.6. Equivalent (von-Misses) stress for the impeller with support angle

The equivalent elastic strain for the impeller with support angle has been analyzed and it is shown as

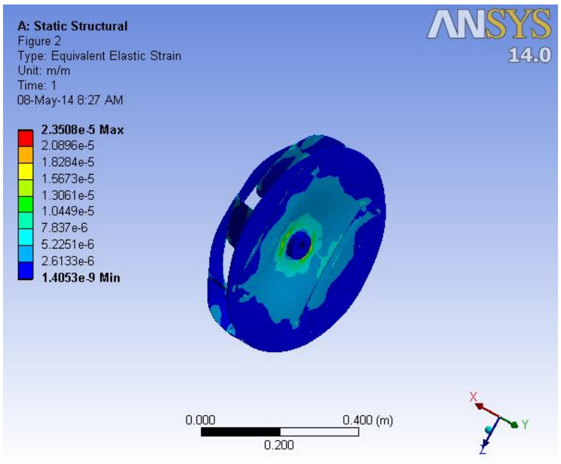

Fig.7. Equivalent elastic strain for the impeller with support angle

The total deformation for the impeller with support angle has been analyzed and it is shown as

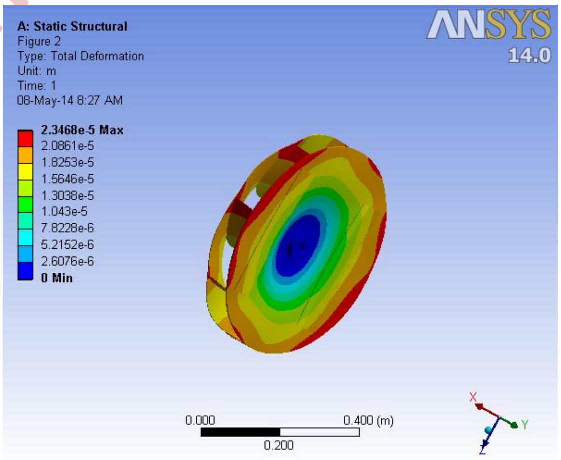

Fig 8. Total deformation without support angle

Table 2 .
Maximum stresses in impeller components with support angle

© 2014, IJOURNALS All Rights Reserved

5. DISCUSSION AND CONCLUSION

It is seen that the stresses in the impeller components are reduced from both the cases by using support angle at the back plate of the centrifugal fan impeller. The stresses in the impeller components it reduced mainly in the support angle.

The present analysis reveals that, the support angle plays very important role in the reduction of stresses in impeller components. It is observed that, use of support angle has reduced the stresses in impeller components by more than 50% as compared with the impeller without support angle. The reduction in the stresses in impeller components due to use of support angle is theoretically verified. The theoretical values are in close agreement with finite element results.

Due to reduction in the stress level because of support angle, it is observed that, the same impeller can be used at higher speed keeping the stress level within acceptable limit.

6. REFERENCES

[1] H. Haerle, The strength of rotating discs, Engineering 106 (1918) 131–134.
[2] J.W. Glessner, A method for analysing stresses in centrifugal impellers, ASME paper no. 54-A-167, 1967.
[3] E.J. Deutsch, Method of stress analysis for shrouded discs, Aerospace Eng. 21 (3) (1962) 24–30.
[4] B.P.C. Ho, Procedure for calculating stresses in centrifugal impeller with cover disc, J. Eng. Power, Trans. Am. Soc. Mech. Engrs. 88 (1966) 395.
[5] D.A. Thurgood, Stresses in asymmetric discs, J. Strain Analysis 4 (1) (1969) 65–73.
[6] R.G. Patton, Stresses in centrifugal fan impellers, Proc. Inst. Mech. Engrs. 187 (28) (1973) 309–315.
[7] R. Bell, P.P. Benham, Theoretical and experimental stress analysis of centrifugal fan impeller, J. Strain Anal. 13 (3) (1978) 141–147.
[8] V. Ramamurti, P. Balasubramanian, Steady state stress analysis of centrifugal fan impeller, Comput. Struct. 25 (1) (1987) 129–155.
[9] D.V. Bhope, M.G. Bhat, Stress analysis of centrifugal fan impeller by finite element method, J. Inst. Engrs. (Mech. Eng. Div.) 70 (1990) 111–113.
[10] M.S. Nabi, N. Ganeshan, Stress analysis of composite centrifugal fan impeller using the cyclic symmetric approach, Comput. Struct. 48 (5) (1993) 781–785.
[11] D.V. Bhope, P.M. Padole, Effect of stiffening rings on the stress distribution in centrifugal fan impeller, International Conference CCM 98, Lyon, France, 1998.
[12] D.V. Bhope, P.M. Padole, Effect of location and size of stiffening rings on the stress distribution in centrifugal fan impeller, International Conference ECCM 99, Munich, Germany, 1999.
[13] G.R. Desai, S.A. Badve, FEM analysis of centrifugal fan impeller, Nisa User s Conference, Banglore, India, 1997.
[14] D.V. Bhope, P.M. Padole, Proposed experimental techniques for determination of stresses in centrifugal fan impeller, National Conference on Machines and Mechanisms, IIT Bombay, December 1999, pp. 52–63.
[15] F.P. Bleier, Fan Handbook––Selection, Application and Design, first ed., McGraw-Hill, 1998.
[16] W.C. Osborne, Fans, second ed., Pergamon Press, 1977.
[17] Bruno Eck, Fans, fifth ed., Pergamon Press, 1972.
[18] T. Baumeister, Fans, first ed., McGraw-Hill, 1935.
[19] Edwin P. Anderson, Rex Miller, Electric Motors, D.B. Taraporewala, India, 1983.
[20] B.C. Nakra, K.K. Choudhry, Instrumentation Measurement and Analysis, Tata McGraw-Hill, India, 1985.

IJSHRE

© 2014, IJOURNALS All Rights Reserved