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ANALYSIS OF RADIATOR FAN OF WDM-2 LOCO ENGINE FOR EFFICIENCY IMPROVEMENT

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Abstract

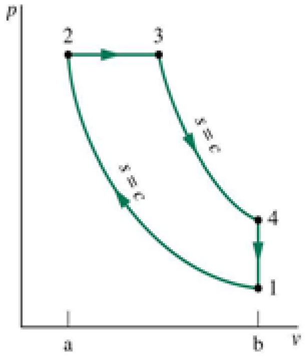
An Railways are the most efficient and effective means of land based transport system all over the world. Indian railways is one of the biggest and busiest rail networks in the world, transporting 16 million passengers and more than one million tones of freight daily. To run such a large system includes lot of complications and problems both technical and non-technical. Railway cooling is one of the most important components in railway vehicles with regard to operation. Since failure in railway cooling system can cause a major breakdown, the objective is to do analysis of cooling system to increase the cooling efficiency of WDM2 class 2600HP diesel engine electric locomotive with DC-DC transmission. Without doing major changes in main cooling system, most effective and economical method is to increase radiator fan rpm. Using Pro-E Wild Fire 2.0 fan blades were modeled with the accurate dimensions. For the increased cooling fan speed, CFD analysis performed using the software FLUENT© and the simulation of the complete flow has been made. Further the finite element analysis is performed using the software ANSYS© to ensure safe design and to avoid resonance. Remarkable increase in efficiency (10-15%) found, presented in this paper.

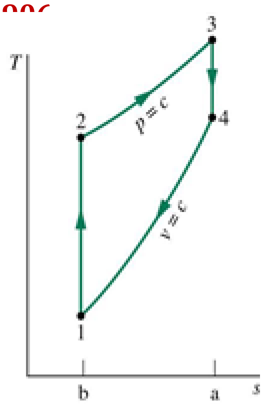
***Keywords**: Radiator fan, resonance, cooling efficiency, finite element analysis, CFD analysis.*

I. INTRODUCTION

In present cooling system addition of high capacity expresser which adds to cooling load, necessitates alternative mean to increase efficiency. For this purpose most effective and economical method is to increase radiator fan rpm. Thus it is necessary to analyze fan with the said modifications.

Fig.1.1 Effect of overheating of engine due to improper cooling system Engine works on the Diesel Cycle:





Process 1-2: compression.
Process 2-3: Fuel Injection & Combustion.
Process 3-4: Expansion.
Process 4-1: Exhaust.

Water Cooling System

Water cooling system consists of the components as shown in the figure

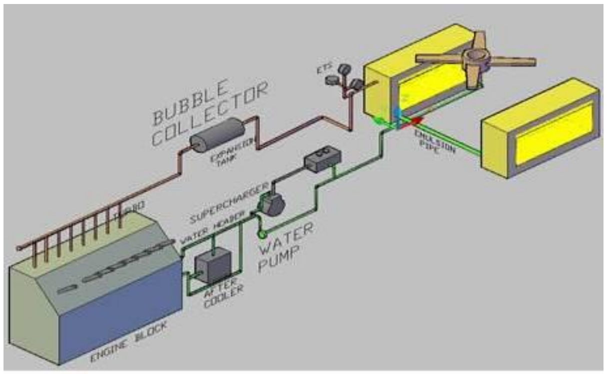


Fig.1.3 Water Cooling System

II. DATA COLLECTED

Radiator Fan

Fan diameter (D): 66 inch

For fan speed 1100 rpm

Velocity of air (v) = 16m/s……… (From Anemometer)

Mass flow rate of air

$Q_a = \pi/4 * D^2 * v$
$= \pi/4 * (1.676)^2 * 16$
$= 35.32\ m^3/s.$
$= 38{,}000$ cfm.

For fan speed 1300 rpm

Velocity of air (v) = 18m/s………… (From Anemometer)

Mass flow rate of air

$Q_a = \pi/4 * D^2 * v$
$= \pi/4 * (1.676)^2 * 18$
$= 39.72\ m^3/s.$
$= 42{,}000$ cfm.

The air discharge velocity is measured by a handheld anemometer along the surface of a fan blade. Once the discharge velocity profile is known, the dynamic pressure can easily be determined using Bernoulli's equation. The air velocity is measured at an equally spaced distance along the surface of the fan blade. The result shown in Figure is the average velocity at selected radial locations on the fan blade. The corresponding dynamic pressure is shown in Figure it is expected that the velocity of air would increase exponentially from the hub of the blade to the tip. However, the measured results show that the real situation is very much different than what is expected. Figure shows that the velocity increases slowly close to the hub of the blade before a sharp increase is observed.

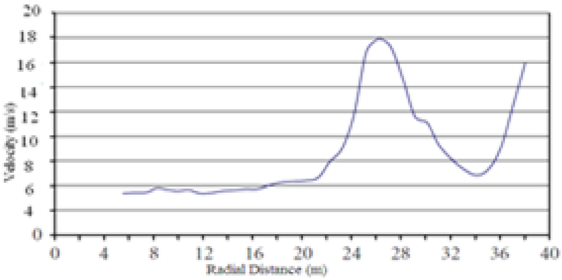


Fig.2.1 Velocity profile

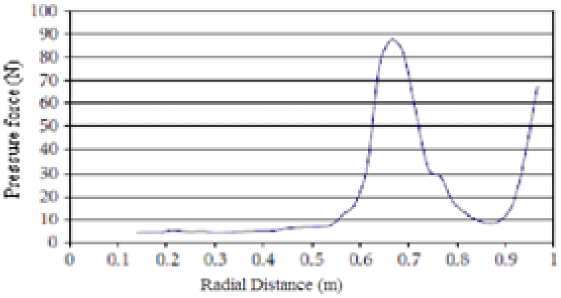


Fig.2.2 Pressure profile

Modelling of fan blade

For the modeling of aero foil Pro-E Wild Fire 2.0 is used as a 3-D modeling tool. The wheel set is modeled with the accurate dimensions.

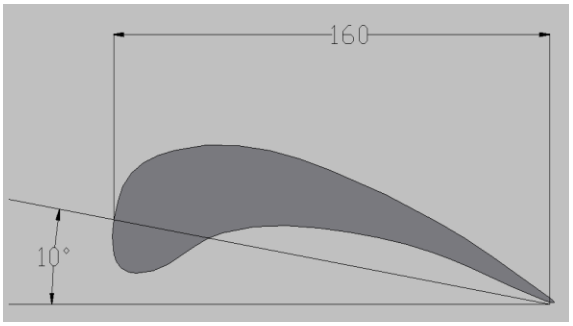


Fig.2.3 Aero foil

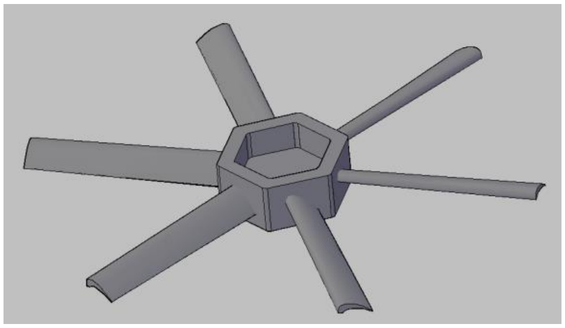


Fig.2.4 Assembly

III. ANALYSIS

CFD ANALYSIS: The problem to be considered is shown schematically in Figure. Due to the cyclic nature of the problem, only one fan blade is modeled. The grid is set up with periodic boundaries on either side of the domain. A velocity inlet is used at the upstream boundary and a pressure outlet at the downstream boundary. The lower wall is assumed to be rotating with the blade, while the upper wall is stationary. Note that a blade tip clearance gap is not modeled in this problem.

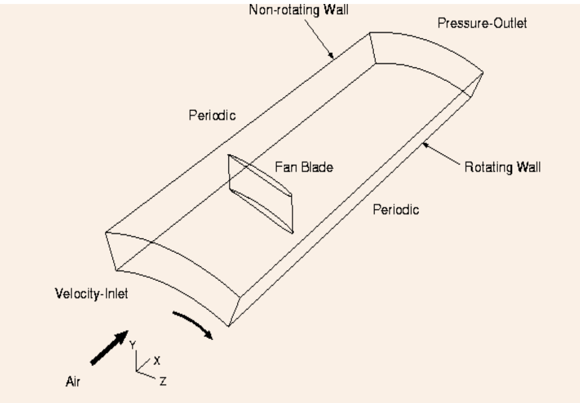


Fig. 3.1 Schematic diagram

This model is powerful in that multiple rotating reference frames can be included in a single domain. The resulting flow field is representative of a snapshot of the transient flow field in which the rotating parts are moving.

Table-1 Properties of cooling air

Sr. no.	Properties	symbol	value
1	Velocity	v	18m/s
2	Density	ρ	$1.225kg/m^3$
3	Specific heat	C_P	1.005kJ/kg k
4	Thermal conductivity	k	$0.01m^2/s^2$
5	Temperature difference	δt	318 k

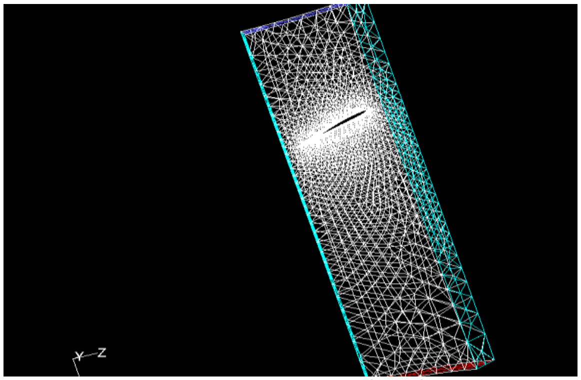


Fig.3.2 Graphics Display of Surface Grid

The radial equilibrium boundary condition provides a better exit pressure distribution for rotating flows such as fans so is used.

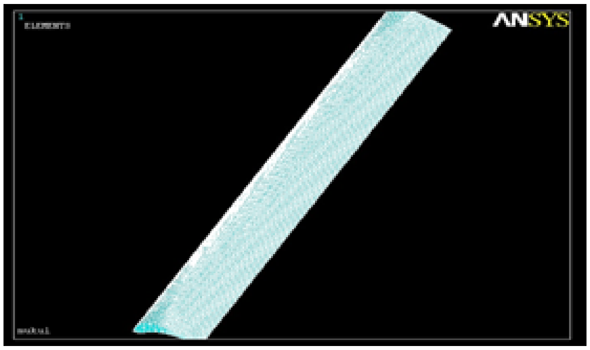


Fig. 3.3 Relative Velocity Vectors on the Midspan Plane

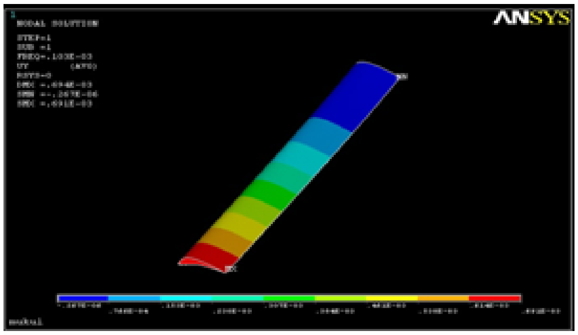
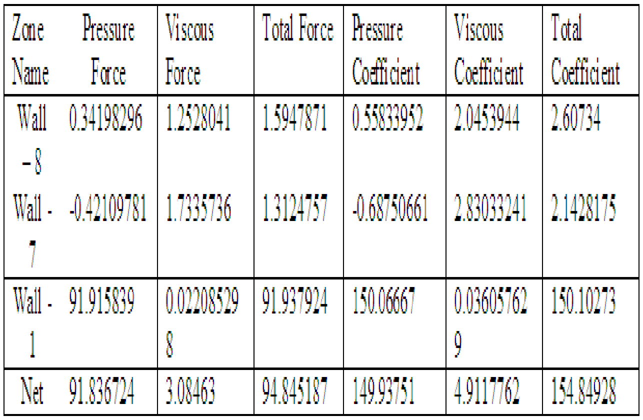


Fig.3.4 Contours of Static Pressure on the Upstream Side of the Fan Blade

The contour plots illustrate the pressure rise which is imparted on the fluid by the fan blade. Also, the pressure field on the upstream surface displays a highly non-uniform radial pressure distribution. The low pressure zone near the leading edge of the blade tip indicates a large acceleration of the flow in that region. This contrasts with the pressure field on the downstream surface, which is relatively uniform.

Table-2 Pressure value over blade wall



Zone Name	Pressure Force	Viscous Force	Total Force	Pressure Coefficient	Viscous Coefficient	Total Coefficient
Wall –8	0.34198296	1.2528041	1.5947871	0.55833952	2.0453944	2.60734
Wall -7	-0.42109781	1.7335736	1.3124757	-0.68750661	2.83033241	2.1428175
Wall -1	91.915839	0.022085298	91.937924	150.06667	0.036057629	150.10273
Net	91.836724	3.08463	94.845187	149.93751	4.9117762	154.84928

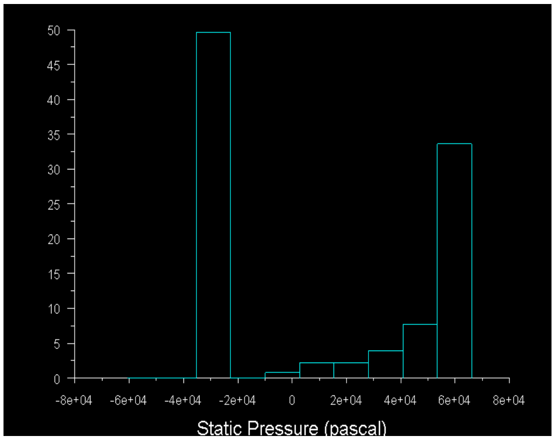


Fig. 3.5 ***Static pressure histogram***

Aerodynamic loads for the angle of attack Ø=30oin terms of pressure variation over the aerofoil profile have been obtained using CFD package FLUENT©. Pressure force over airfoil of 91 N is used for stress analysis.

Finite element analysis

The stiffness of blade is influenced by aerodynamic force, centrifugal force, the natural frequency and modal shapes.

In order to avoid the resonance, natural frequency was found out and modal shapes found of rotor blade and analyzed dynamic characteristics.

To simplify the modeling of this problem, a model of the FAN is provided an IGES file.

Material properties:

The materials of the fan blade have been considered as isotropic with ideal elastic-plastic behaviors which are obtained from the IRS-std-manual.

Table-3 Meshing of Blade

	Volume Tetrahedral Mesher (Auto Global)	Standard Tetrahedral Mesher (Global)
No. of Elements	722035	28889
No. of Nodes	180508	7223

Table-4 Material Properties

Material	Density (kg/m3)	Young's Modulus (Mpa)	Poisson's Ratio	Tensile Strength (Mpa)
Table-3 Meshing of Blade Aluminum24534	2180	72000	0.33	375
TitaniumTi4.5Al3V2sMo2Fe	4440	128000	0.33	960

The finite elements used for the FEM analysis are Solid 185, Targe 170 and Contact 174.The Mesh Tool is used to generate the meshed FEM model. For meshing the 3-D solid element 'Solid 185 Tetrahedra' is used. The mesh is refined in the wheel seat zone where the maximum values of stress and related gradients are foreseen. This step reduced the solving time considerably.

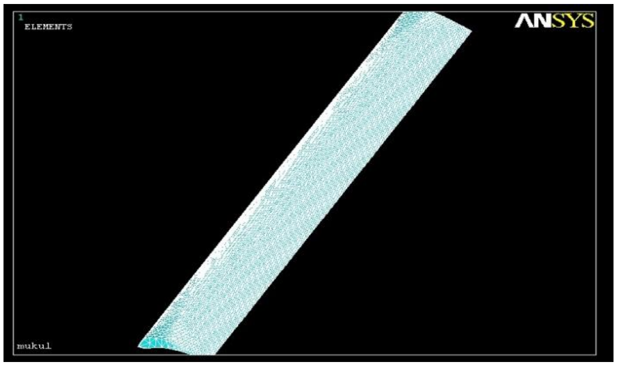


Fig.3.6.Meshing of Blade

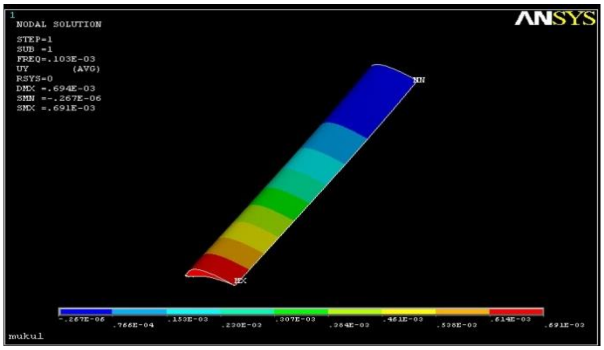


Fig.3.7 Stress Distribution

First five modes were found tabulated in table

Table-5 Modal analysis data

SET	TIME/ FREQ.	LOAD STEP	SUB STEP	CUMMU-LATIVE
1	0.10303E-03	1	1	1
2	0.37289E-03	1	2	2
3	0.64171E-03	1	3	3
4	0.17790E-02	1	4	4
5	0.18531E-02	1	5	5

IV. RESULT & DISCUSSION

Effectiveness of radiator

Flow rate of water = 0.04095m^3/s
Density of water (ρ_w) =1000kg/m^3
Mass flow rate of water (m_w) =40.95kg/sec
Specific heat for water (cp_w) =4.186kJ/kgk

For 1100 rpm:-

$th_1 = 86^{\circ}C$, $th_2 = 78.6^{\circ}C$, $tc_1 = 30^{\circ}C$,
$tc_2 = 45^{\circ}C$
Flow rate of air $(Q_{a1}) = 35.32 m^3/s$
Mass flow rate of air $(m_{a1}) = 43.267 kg/sec$
Specific heat of air $(c_{pa}) = 1.005 KJ/kg\text{-}k$
Hot fluid capacity= $m_w c_{pa}$
$c_n = C_{max} = 40.95*4.186 = 171.42 kJ/sec$
Cold fluid capacity = $m_{a1}\, c_{pa}$
$c_c = C_{min} = 43.267*1.005 = 43.48 kJ/sec$
Effectiveness of radiator

$$\sum_1 = \frac{C_{min}\,(tc_2-tc_1)}{C_{max}\,(th_1-th_2)}$$

$$= \frac{43.48(45-30)}{171.42(86-78.6)} = 0.52$$

For 1300 rpm:-

$th_2 = 76.9^{\circ} C$
Flow rate of air $(Q_{a2}) = 39.72 m^3/s$
Mass flow rate of air $(m_{a1}) = 65.51 kg/sec$
Hot fluid capacity = $m_w\, c_{pa}$
$c_n = C_{max} = 40.95*4.186 = 171.42 kJ/sec$
Cold fluid capacity = $m_{a1}\, c_{pa}$
$c_c = C_{min} = 65.19*1.005 = 65.51 kJ/sec$
Effectiveness of radiator

$$\sum_2 = \frac{C_{min}\,(tc_2-tc_1)}{C_{max}\,(th_1-th_2)}$$

$$= \frac{65.51(45-30)}{171.42(86-76.9)} = 0.63$$

Change in Effectiveness = (0.63-0.52)*100
= 11%

Thus increase in cooling fan speed from 1100 rpm to 1300 rpm, 10-15% increase in effectiveness of radiator found, depending upon atmospheric conditions at various locations.

Table-6

Permissible Yield Stress (MPa)	Induced Stress (MPa)
310	220
Natural Frequency (rad/s)	Excitation Frequency (rad/s)
195	136

V. CONCLUSION

Induced stress is less than permissible stress so fan is safe in static condition. The fan is operated at ‘Excitation Frequency’ which is quite less than the Natural Frequency, so it is safe in dynamic condition also. By increasing the fan speed there was increase the mass flow rate of air to increase the temperature gradient between the radiator core inlet and outlet temperature thereby enhancing the cooling efficiency.

REFERENCES

1. *Finite element analysis of fan blade, Sandeep Dhar P. Seshu B. Roy Department of Mechanical Engineering, Indian Institute of Technology Bombay, Mumbai-76.*
2. *Radiator fan assembly DLW drg TPL-0165, Sheet 1of 7,Alt p'.DLW Pt. No-11420091.*

3. *Pro/Engineer Reference Guide, CADD Centre, India.*
4. *ANSYS® Reference Guide, CADD Centre, India.*
5. *Maintenance Manual for WDM2 locomotive, Indian Railways.*