Correlation between Fan Blade Diameter and Heat Dissipation Area of a Radiator

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ABSTRACT

In any cooling system of a motor vehicle increase in Fan blade leads to increase in Heat dissipation area of radiator and vice versa. This study examined the effect of Fan blade diameter on the heat dissipation area of radiator and FORTRAN computer code was developed for computation of fan blade diameter corresponding to heat dissipation area of radiator. Aided by the developed software, the effect of increasing fan blade diameter on heat dissipation area of radiator is investigated. Results obtained for case studies examined at varying the depth of radiator, showed that Heat dissipation area of radiator increases with Fan blade diameter. The numerical results were processed with the EXCEL package, which yield a relationship of the form; $A_{hrad} = 70.71(D_{bl})^4$ *, where a is real characteristic values of a particular problem.*

Keywords: *Cooling system, Fan blade, radiator, heat dissipation.*

INTRODUCTION

Heat is a form of energy that has wide application in engineering and technology. Motor vehicle engine is one of the greater area in which application of heat is imperative. In the world today, particularly in Nigeria, Motor vehicle engine are mainly internal combustion one that exploits petroleum products as fuel (Abdrahim et al, 2003 and Salami, 2004). It is established (Abdrahim et al, 2003) that about 3- million tons and 5- million tons of Diesel and Gasoline are consumed annually in Nigeria respectively. The combustion process of petroleum product generates large amount of heat that requires proper regulation for automobile internal combustion engine efficiency. It is estimated that out of heat generated by internal combustion engine as a result of fuel combustion in the cylinder, thirty- five percent (35%) passes through the wall of cylinder (Banga and Singh, 1987). This is rejected to the cooling system. Cooling system is one of the major motor vehicle engine systems that ensure the temperature of the engine is kept within the limit imposed by the need of safety and efficiency (Khovakh et al, 1977). The cooling agent customarily employed is air or liquid, thus air or liquid (water) cooling system. For effective control of heat in water cooling system, "Heat Exchanger" is employed. It is a device that transfers heat from region of higher temperature to lower temperature through fluid separated by a solid (Alamu et al, 2003, Banga and Singh, 1987 and Rogers and Mayhew, 1992). It's labeled various names depending on the particular purpose it serves, thus the name Boiler, Evaporator, Condenser or Radiator. Among the factors that determine the efficiency of water-cooling system is the Fan blade diameter and Depth of radiator. Fan contains shrouds and blades, it drawn in air through the radiator thereby reducing the temperature of the water (Bent and Stephens, 1974 and Dolan, 1996). Fan increases air flow allowing the use of smaller radiator, which can dissipate the required amount of heat (Lateef et al, 2004). Radiator on the other hand, is a vessel that received and store heated water from the engine and exposes it to the Fan. The matrix of the radiator may be tube and fin (Figure 1) or film (cellular) type. According to Abdrahim et al (2003), Nigeria is now a dumping ground for used vehicle commonly called " TOKUNBO' due to poor economy and dejected condition of Auto- assembly plant in the country. It is a crystal fact that Tokunbo vehicle are associated with one problem or the other most especially overheating and replacement of worn out parts. Considering the climatic conditions, there is need to change radiators to suit Nigeria environment. This is usually done without any consideration for Fan blade diameter to march radiator dimensions, such as depth and heat dissipation surface area, therefore, leading to overheating of such engine. The total dimensions of radiator exposed to the fan determine the amount of air stream drawn in which also determine the quantities of heat removed from hot circulating water. From the foregoing, the interaction between the radiator dimensions (depth (Figure 1) and heat dissipation area) and fan blade diameter gives the efficiency of the cooling system, hence the need for establishing the degree of their dependence. This will be a useful yardstick in generating the necessary information, which could aid perfect choice of both radiator and fan blade. This relationship is determined in this work by integrating general design equation for fan blade diameter into volumetric coefficient of compactness (Khovakh et al, 1977). The resulting expression is developed into FORTRAN 77 computer codes to generate precision values for fan blade diameter corresponding to series of Heat dissipation area of radiator values.

$V_r =$

MATERIALS AND METHOD

The general equation for volumetric coefficient of compactness of a radiator is given (Khovakh et al, 1977) as:

$$V_{rad} = \frac{A_{rad}}{V_r} \qquad \text{..1}$$

where,

$V_{rad} =$ Volumetric coefficient of compactness (m^{-})

$A_{rad} =$ Total heat dissipation area (m^2)

The volume of radiator has been expressed (Champion and Arnold, 1970) as:

$$V_r = A_{frad} \cdot D_{rad} \qquad \text{..2}$$

where,

Volume of radiator (m^3)

$D_{rad} =$ Depth of radiator (m)

The design equation for fan blade diameter is given (Khovakh et al, 1977) as:

$$D_{bl} = 2\sqrt{\frac{A_{frad}}{\pi}} \qquad \text{...3}$$

where,

D_{bl} = Fan blade diameter (m)

A_{frad} = Face area of radiator (m^2)

From equation 1,

$$A_{hrad} = V_{rad} \cdot V_r \qquad \text{...4}$$

Put equation 2 into equation 4,

....5

Equation 3 can be written as:

....6

Using equations 5 and 6,

$$A_{hrad} = \frac{V_{rad}\,\pi\,D_{rad}\,(D)^2_{bl}}{4} \qquad \text{...7}$$

The value of depth of radiator D_{rad}, Fan blade diameter D_{bl} and Volumetric coefficient of Compactness V_{rad} are all features of design condition for determining the efficiency of water cooling system of a motor vehicle. Therefore, if volumetric coefficient of compactness V_{rad} and Depth of radiator D_{rad} is held constant, the effect of the fan blade diameter on the Heat dissipation area of radiator can be deduced from equation 7. Computer simulation of equation 7 was carried out. The program developed in FORTRAN 77 was structured in interactive data input form. The software determines the relationship between the Heat dissipation area of radiator and Fan blade diameter of a cooling system of a motor vehicle engine. Data generated through the program were then processed with EXCEL package to obtain mathematical expression, which describes the relationship between Fan blade diameter and Heat dissipation area of radiator. A typical experimentation was carried out with the following parameter, V_{rad} = 900 (m-), π = 22/7, = 0.06 (m) and D_{bl} = 0.225 (m). Keeping all other parameters constant, the Fan blade diameter varied from 0.225 (m) to 0.65 (m) resulting in different values of Heat dissipation area. Also, for B, C, D and E cases using increment in Depth of radiator at a rate of 0.02 (m) and variation of Fan blade diameter between 0.25 to 0.65 (m) to generate different values for Heat dissipation area of radiator.

RESULTS AND DISCUSSION

Table 1 presented the result obtained from the Heat dissipation area increases with increase in Fan blade diameter. Also, increase in Depth of radiator at constant Fan blade diameter leads to increase in the Heat dissipation area of radiator. Accordingly, the data of the output of the computer program (Table 1) were further processed with EXCEL package to develop a mathematical relationship between Heat dissipation area and Fan blade diameter in water cooling engine. As evident from Figure 2 and 3, the case considered (A-E) gave quantitative expression in respective order as presented below:

$$A_{hrad} = 0.017\,(D)^2_{bl} + 0.390\,D_{bl} + 2.244$$

$$A_{hrad} = 0.022\,(D)^2_{bl} + 0.520\,D_{bl} + 2.992$$

$$A_{hrad} = 0.028\,(D)^2_{bl} + 0.650\,D_{bl} + 3.740$$

$$A_{hrad} = 0.033\,(D)^2_{bl} + 0.780\,D_{bl} + 4.489$$

$$A_{hrad} = 0.039\,(D)^2_{bl} + 0.910\,D_{bl} + 5.237$$

Generally, these relationships are non - linear (quadratic) and of form:

$$A_{hrad} = a\,(D)^2_{bl} + b\,D_{bl} + c$$

Where *a, b* and *c* are real characteristic values of the particular problem of cooling system of automobiles. It can thus be deduced that larger Heat dissipation area of radiator requires corresponding larger Fan blade diameter in agreement with anon-linear relationships that boost cooling efficiency of automobile engines. The correlations above are for the specific cases considered. An attempt to obtain a single correlation to generalize the results for the relationship between Heat dissipation area of radiator and Fan blade diameter using line of best fit (Figure 4) generated an approximated power function:

$$A_{hrad} = 70.71 D^4_{bl}$$

CONCLUSION

The paper discusses the relationship between the Fan blade diameter and Heat dissipation area of radiator for an effective cooling system of motor vehicle engine. A computer program is developed to evaluate the relationship and conclusion is made. The results confirm that increase in the Fan blade diameter leads to increase in Heat dissipation area of radiator. Further analysis showed that Fan blade diameter increases non-linearly with Heat dissipation area of radiator, and conclusively, for a perfect mathematical relationship and also for part replacement between Fan blade diameter and Heat dissipation area of radiator with respect to Depth of radiator, a power equation resulted: $A_{hrad} = aD^4_{bl}$ with (*a*) being a real value characteristic dependent of specific Depth of radiator.

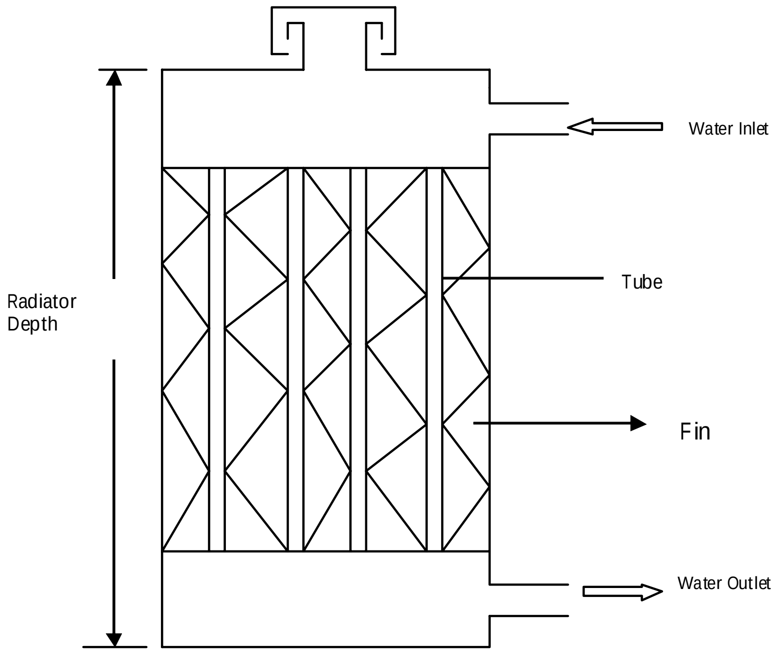

Fig 1: Tube and Fin radiator

Table 1: Programme Output for Fan Blade Diameter Variation with Heat Dissipation Area of Radiator at various Depth of Radiator (m)

S/N	BLADE DIAMETER (m)	DEPTH OF RADIATOR (m)				
		0.06	0.08	0.10	0.12	0.14
			HEAT DISSIPATION AREA (m2)			
1	0.250	2.6518	3.5357	4.4196	5.3036	6.1875
2	0.270	3.0930	4.1241	5.1551	6.1861	7.2171
3	0.290	3.5682	4.7577	5.9471	7.1365	8.3259
4	0.310	4.0775	5.4365	6.7956	8.1548	9.5139
5	0.330	4.6205	6.1606	7.7008	9.2409	10.7811
6	0.350	5.1975	6.9300	8.6625	10.3950	12.1275
7	0.370	5.8085	7.7446	9.6808	11.6169	13.5531
8	0.390	6.4534	8.6045	10.7556	12.9068	15.0579
9	0.410	7.1322	9.5097	11.8871	14.2645	16.6419
10	0.430	7.8450	10.4601	13.0751	15.6901	18.3051
11	0.450	8.5918	11.4557	14.3196	17.1836	20.0475
12	0.470	9.3725	12.4966	15.6208	18.7449	21.8691
13	0.490	10.1871	13.5828	16.9785	20.3742	23.7699
14	0.510	11.0357	14.7142	18.3928	22.0713	25.7499
15	0.530	11.9182	15.8909	19.8636	23.8364	27.8091
16	0.550	12.8346	17.1129	21.3911	25.6693	29.9475
17	0.570	13.7850	18.3801	22.9751	27.5701	32.1651
18	0.590	14.7694	19.6925	24.6156	29.5388	34.4619
19	0.610	15.7877	21.0502	26.3128	31.5753	36.8379
20	0.630	16.8399	22.4532	28.0665	23.6798	39.2931
21	0.650	17.9261	23.9014	29.8768	35.8521	41.8275

Source: Experimentation, 2011

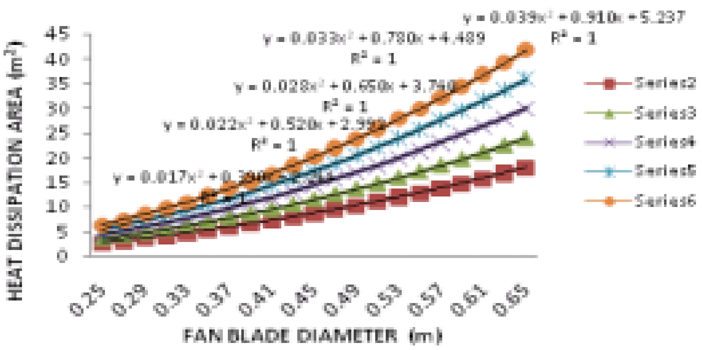

FIG. 2 RELATIONSHIP BETWEEN HEAT DISSIPATION AREA AND FAN BLADE DIAMETER AT VARYING DEPT OF RADIATOR

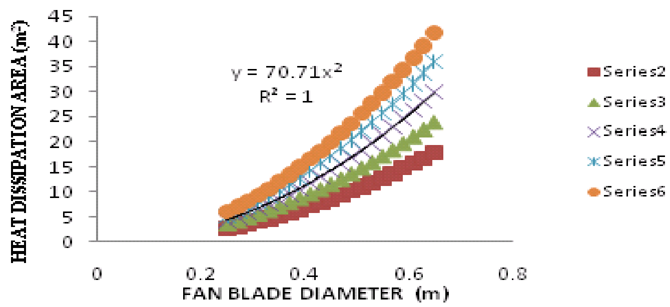

FIG 3: VARIATION OF FANBLADE DIAMETER WITH HEAT DISSIPATION AREA OF A RADIATOR

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