Theoretical Calculation of Contribution of Mobile Air Conditioning System on Fuel Economy, Emission, Soaking Temperature and Refrigerant Quantity

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Abstract:- Mobile air conditioning system has major contribution on fuel economy, emission, soaking temperature and refrigerant quantity. This paper quantifies the impact based on theoretical calculation and the reduction with glass film.

Typically there is increase of 2 to 3Liter per 100Km fuel consumption and 0.16gram per mile NOx with AC ON compared to AC OFF. By reducing the cooling load of mobile air conditioning (MAC) system, fuel consumption and NOx generation can be reduced.

When vehicle is parked in hot sun with doors and windows closed, passenger compartment temperature increases drastically, because of solar load and greenhouse effect. With glass film on wind shield glass and driving habits like driving with window open for 3 to 5 min can reduce soaking temperature and further impact on fuel consumption.

Typically for mobile air conditioning system (MAC) refrigerant quantity requirement is 2.5 to 3.5 kg per tone of refrigeration. By reducing the cooling load of MAC smaller capacity system can be designed which will reduce use of refrigerant which has glowal warming potential (GWP)

Keywords:-
MAC- Mobile Air Conditioning System
GWP- Global warming potential

I. INTRODUCTION

Mobile air conditioning system has major contribution on fuel economy, emission, soaking temperature and refrigerant quantity. This paper quantifies the impact based on theoretical calculation and the reduction with glass film.

MAC cooling load is calculated for glass with different transitivity in different ambient condition.

II. MAC COOLING LOAD

The Cooling load calculation is based on peak or near-peak conditions. The design cooling load (or heat gain) is the amount of heat energy to be removed to maintain the passenger cabin at design temperature. When worst case outdoor design temperature is being experienced.

Net overall thermal load (QTot) encountered by the cabin is sum total of metabolic load (QMet), Air Infiltration Load (QInfil), Solar Load (QSolar) etc.

Metabolic Load QMet = Sum of (M x BSA), Where M is the passenger metabolic heat production rate.For a driver and a sitting passenger, the values can be estimated as per ISO 8996 Ergonomics of the thermal environment Determination of metabolic rate. Averge BSA (body surface area) is 1.73 m2. For a single person assuming average heat load = 116 W (as per ASHRAE), QMet = Number of passengers * 116 W.

Air Infiltration Load (QInfil) is Amount of air leaked as per thump rule is ½ V m3/hr; (V = vehicle speed in km/h), Assuming 50 kmph, air volume leaked = 25 m3/hr. Air Infiltration Load = 25 x Air density x (Enthalpy of Infiltered Air -Enthalpy of Cabin Air).

Heat generated by blower motor = Blower Wattage x Load factor / Efficiency.

Solar Load (QSolar): Solar radiation hits ceiling, side wall glass etc. directly–External surface temperature depends on solar radiation and plate absorption ratio (For black plate, a = 0.89, a = absorptivity of the metal surface).Vehicle body is assumed black for conservative design. Solar radiation doesn't hit directly for places like floor, dash board etc. Vehicle exterior body material (single or multiple layers) is selected with low thermal conductivity. Increases thermal resistance. less conductive heat transfer from vehicle surface to the interior.Heat penetration from glass surface depends on respective window inclination angle. Higher the angle w.r.t. horizontal direction, lesser the load and vise versa.The projected area decreases with an increase in angle .

Heat Load due to Sheet Metal = Us*As*(ΔT)s

Heat Load due to Glasses = Ug*Ag*(ΔT)g + (diffused radiation) + (direct radiation)*cos(i)*Ag*τ

U = Overall Heat Transfer Coefficient,Roof, Door and Rear Wall Sheet Metal (W/m2K)=1/(1/hi + t1/k + t2/k),

ΔT = Surface Temperature - Cabin Temperature (°C), i = Sun's incidence angle on glass, τ = transmissivity of glass.

- *Reduction in Fuel Consumption by Reducing MAC Cooling Load.*

By reducing heat load on MAC the fuel consumption is reduced. Assuming 3 L/100 km difference between AC ON and OFF and same reduction in fuel economy as heat load. Below is the reduction in fuel consumption with different transmissibility glass film.

Reduction in fuel consumption (L/100km)			
Ambient Temperature (^{0}C)	**Reduction in glass transmitance with film (%)**		
	30%	**40%**	**50%**
25	0.34	0.45	0.57
17.5	0.30	0.40	0.51
10	0.26	0.35	0.43

Table 1

- *Reduction in NOx Generation by Reducing MAC Cooling Load.*

By reducing heat load on MAC the fuel consumption is reduced. Assuming 0.16 g/mile difference between AC ON and OFF and same reduction in fuel economy as heat load. Below is the reduction in NOx generation with different transmissibility glass film.

Nox generation reduction (g/mile)			
Ambient Temperature (^{0}C)	**Reduction in glass transmitance with film (%)**		
	30%	**40%**	**50%**
25	0.018	0.024	0.030
17.5	0.016	0.022	0.027
10	0.014	0.018	0.023

Table 2

- *Reduction in Refrigerant Quantity*

By reducing heat load on MAC the refrigerant quantity is reduced which has global warming potential (GWP). Typical refrigerant quantity requirement is 2.5 to 3.5kg /Tone of refrigeration. Below are the calculated values of reduction in refrigerant quantity with MAC system designed for lower cooling load with different transmissibility glass film.

Reduction in Refrigerant quantity (g)			
Ambient Temperature (^{0}C)	**Reduction in Window transmittance**		
	30%	**40%**	**50%**
25	173	230	288
17.5	144	192	240
10	115	154	192

Table 3

- *Reduction in Soaking Temperature.*

By reducing heat load on MAC with lower transitivity glass film soaking temperature is reduced because of lower transmitted solar radiation. Below are the reduction in soaking temperature calculated.

Reduction in Soaking temperature (^{0}C)			
Ambient Temperature (^{0}C)	**Reduction in Window transmittance**		
	30%	**40%**	**50%**
25	16	17	21
17.5	11	14	18
10	8	11	14

Table 4

III. SUMMARY/CONCLUSIONS

Mobile air conditioning system has major contribution on fuel economy, emission, soaking temperature and refrigerant quantity. By reducing heat load with lower transmissibility glass film there is considerable in improvement in fuel economy, emission, soaking temperature and refrigerant quantity.

REFERENCES

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