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Main properties of heat shields used in modern vehicles

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Abstract: In the article are shown main physical phenomena which are affecting heat shields used in cars, such as thermal and acoustic functions. Physical phenomena such as conduction, convection and radiation heat transfer being described. Acoustic physical equations of reflection, absorption and transmission being described in area of heat shields requirements during design phase. Based on these phenomena, requirements for heat shields used in vehicles can be described to find optional heat shield composition. As a main requirement is to place a thermal barrier between heat source and car parts, in addition mechanical shield for many different factors and using materials with proper acoustic absorption gives also acoustic insulation, which is often required by customers.

Key words: heat shields, acoustic, thermal management, car, conduction, convection, radiation, transmission, reflection, absorption.

1. INTRODUCTION

The areas of a car that develop high temperatures require a highly effective thermal shielding solution. In addition, acoustic protection standards are becoming more and more demanding. Temperature management in modern vehicles is becoming increasingly complex. Tightly placed components, engine encapsulation, minimal cooling air flows, catalytic converter technology and turbochargers result in high temperatures in the engine compartment, across the exhaust system and within the area of the car underbody. At the same time, there is a growing number of temperature-sensitive components that have to be protected from heat. Thermal and acoustic shielding systems help engine and exhaust systems to function safety and effectively. In the process, they are also contributing to enhanced driving comfort and environmental protection [1,2].

2. HEAT SHIELDS FUNCTION AND TYPES

Heat shields have to cover the hot components of a car as far as possible from the heat source and as close as possible to the body of a car. Usually space is limited, in particular in the engine compartment and the underbody area, thus heat shields have normally fairly complex shapes to fit tightly between the different components. The example of heat shield during the work is shown in the figure 1. There are two main types of heat shields: single layer and multi layer;

- single layer: flat, embossed,
- multi layer: double Shell, sandwich, composite.

Main function of heat shields:

- thermal barrier between heat source and heat sensitive components.

As additional functions can be described:

- mechanical protection (chipping, stone impact, water barrier),
- aerodynamic improvement by special design for underbody part,
- improvement of acoustic absorption.

Fig. 1. High efficent turbo charger during work – heated up to glowing temperature [11].

3. THERMAL MANAGMENT

3.1.Conduction

Heat conduction and thermal diffusion is a thermal transfer caused by a temperature difference between two areas of the same medium, or between two media in contact. Regions with greater molecular kinetic energy (hotter) transfer through their thermal energy to regions with less molecular energy by means of direct molecular collisions. Thermal energy is transferred from matter with a higher temperature to matter with a lower temperature in some period of time [3,4,5].

The conductivity phenomenon are mainly driven by:

- the temperature gradient; $\Delta T = T_1 - T_2$,
- the distance (d) between the hot and cold side,
- the capcity of the medium to transfer heat energy internally, also called thermal conductivity (λ).

3.2.Convection

The type of convection is fully dependent of the fluid speed which is natural or forced. Natural convection occurs when the fluid flow is indepdent of any third party influece, however if there is any impact of human being or machine then it is forced convection. The heat transfer due to convection is driven by:

- the temperature difference between the fluid temperature (e.g. air) and the solid,
- the shape of the surface of the solid,
- the convection coefficent (h).

Convection coefficent (h) depends from the properties of the fluid itself and its speed. Medium which are commonly used are; air which can be used for most comon application and special cooland fluid for heat exchangers [3,4,5].

3.3.Radiation

Whatever the temperature is, a system always emits thermal radiation which is more or less intense according to its actual temperature. The wavelenght at which the radiation is emited also depend on its temperature. This heat transfer is the only one to carry into space (no need of material medium), like solar radiation arriving on Earth. However, it is also realized in the fluid certain solid. Energy is carried by photons of light in the infrared and visible portions of the electromagnetic spectrum [3,4,5].

The heat radiation exchanges are driven by:

- by the temperature of the system which is emitting radiation,
- the emissivity of the surface of a material which is its effectiveness in emitting energy as e thermal radiation,
- by the shape of the surface,
- by the physical constatnt (Boltzmann constant, σ)

4. THERMAL MANAGMENT SOLUTIONS:

There are three main function, which are taken under consider during the design of the heat shields:

- heat insluation – main purpose is to modulate the heat transfer due to conduction. To design low thermal conductivities (λ<0,1) must be used material like glass wool, foams or air layer
- heat reflectors - heat shield are mainly used to relfect the heat through heat radiation. To reflect the heat should be used materials with a low emissivity (ε<0,2) such as polished metals which are currently the best solution
- air flow managment - Convection is managed mainly by the control of the air flow around the part to cool down or heat up. To do so the princial concept is to control the air speed or the convection coefficient (h).

Thermal managment is mainly driven by its benefits such as:

- thermal safety
- CO_2 emissions
- thermal comfort

5. ACOUSTIC MANAGMENT

Acoustics is the science of sound, including its production, transmission, and other effects. The term sound implies not only phenomena in air responsible for the sensation of hearing but also whatever else is designed by analogous physical principles. One may speak of underwater sound, sound in solids, or structure-borne sound. Acoustics is distinguished from optics in that sound is a mechanical, rather than an electromagnetic, wave motion. The principle of the sound waves is shown in the figure 2.

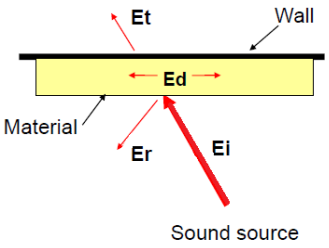

Fig. 2. Incident and reflected energy in the materials. Ei – incident energy, Er - reflected energy, Et – transferred energy, Ed – energy distributed [10].

5.1.Acoustic absorbtion

It is common experience that there exist materials that, when applied on the walls of a room, reduce the noise in the room itself. This noise reduction takes place because of ‘acoustic absorption’ inside the materials. Acoustic absorption is obtained typically from

porous materials (felts, foams) thanks to viscous, thermal and inertial interactions between the structure of the material and the pores. Absorption is effective:
• for reverberant fields,
• in proximity of sources,
• close to leakages [7,8].

5.2.Reflection coefficient

Relfection coeffictien is called „r“ and it is always in comparment of 0<“r“<1 and it is described by equation no. 1 [12,14,16].

$$r = \frac{reflected\ energy}{incident\ energy} \tag{1}$$

5.3.Absorbtion coeffictient

Absorption coefficient „α“ is always in comaprment of 0<“α“<1 and it is described by equation no. 2 which is fully refered to reflection coeficient. In this case there is always foreseen consideration of the higher absorption coefficient the better acoustic performance to be achieved [6,7,8].

$$\alpha = 1 - r \tag{2}$$

5.4.Transmission coefficient

Transmission coefficient describes amount of the energy which is transferred through the medium, by managing distribution of the energy in the materials we are able to moderate acoustic performance of the different elements. „τ” as transmission coefficient, is in compartment of 0<„τ”<1 and it is described by equation no.3 [7].

$$\tau = \frac{transmitted\ energy}{incident\ energy} \tag{3}$$

6. MAIN FUNCTION OF ACOUSTIC HEAT SHIELDS

Currently, there are many types of heat shields in the market, each of them has a different degree of effectiveness. One of them is the conventional heat shield. It works by deflecting heat away from the affected areas. Such shields are usually made of aluminum, due to its light-weight and reflective properties. However, as heat is transferrable via means other than radiation, the effect of reflective heat shields is limited.
As main functions can be described:

- damping: reduction of the body vibration thanks to viscoelastic materials,
- insulation: reduction of the noise transmission through a partition thanks to multilayers based on porous materials and dense materials,

- absorption: absorption of noise close to a source or in a cabin, thanks to the use of porous materials,
- shielding: combination of insulation and absorption close to a source,
- sealing: reduction of sound leakages [10].

7. SUMMARY

There are two main requirements which are firstly considered during the design of the heat shield; it is thermal and acoustic properties. The most important function of thermal management in the vehicles is to protect sensitive plastic components from the effect of heat and to provide optimal thermal comfort for the occupants. Heat shielding products are designed to effectively manage radiant, convective and conductive heat from the front to the back of a vehicle. The number of heat shields per car varies considerably and usually depends from the value of the car or its prestige. Thermo-acoustic heat shields combine effective thermal protection with a reduction of external noises. Nowadays thermo-acoustic heat shields are mainly used for higher class of the cars. However, vehicles have very limited weight so each weight increase leads to unwanted consequences such as CO_2 emission, higher fuel consumption and lower dynamics of the car.

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