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# Analysis of Engine Vibrations in Automobile Propulsion Units and Car Bodies by Double Pulsed Laser Holography

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## 1. Introduction

In the field of sound and vibration analysis holography is a very useful diagnostic method. The double pulse technique especially offers the possibility of visualizing the vibration pattern of an object surface by covering it with a system of interference fringes which are loci of equal displacement. The method works without contact and therefore the vibration of the object is uneffected. During the exposure time the hologram recording arrangement must not move relatively to the object in excess of 1/20 of the wavelength of the laser beam. This of course is a difficulty but the application of a giant pulse laser with extremely short pulse times of about 30 ns as a light source makes it possible to record holograms of car bodies and engine-gearbox-combinations excited by the engine itself.

## 2. Method of Measurement

Figure 1 shows schematically the arrangement for recording holograms of vibrating object surfaces. The laser beam is made divergent by means of a diffusion lens, and then a wedge-shaped beamsplitter divides it into 3 parts. The first one is used for control purposes. The second one is the reference wave which is reflected by a surface-mirror directly on to the photo plate (R). The third part with the highest in-

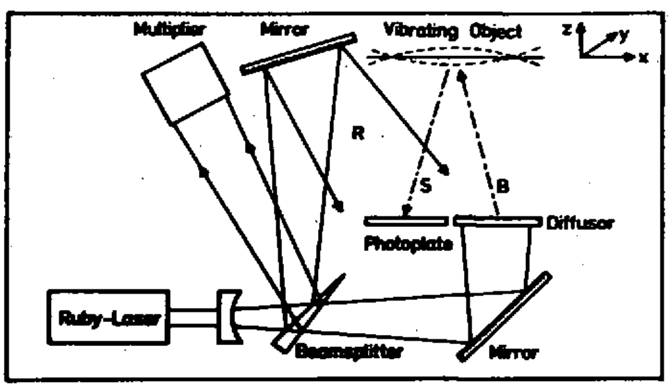


Figure 1

tensity illuminates the surface of the object being holographed (B). The diffusely reflected light wave S contains in form of amplitude and phase all information about the object surface and is called the object wave. At the photo plate it is superimposed on the reference-wave and the resulting interference pattern produces the hologram from which the object wave can be reconstructed. From two holograms of the object surface in the positions $z_1$ and $z_2$ successively recorded on the same plate the object-waves $S_1$ and $S_2$ can be reconstructed simultaneously so that they interfere. The minima are at those points where for the displacement d the formula in figure 2 is satisfied. For any two points on the object the relative displacement $\Delta d$ can be calculated by counting the n interference lines between them. The result is given by the formula $\Delta d = n \cdot \lambda/(\cos\alpha + \cos\beta)$.

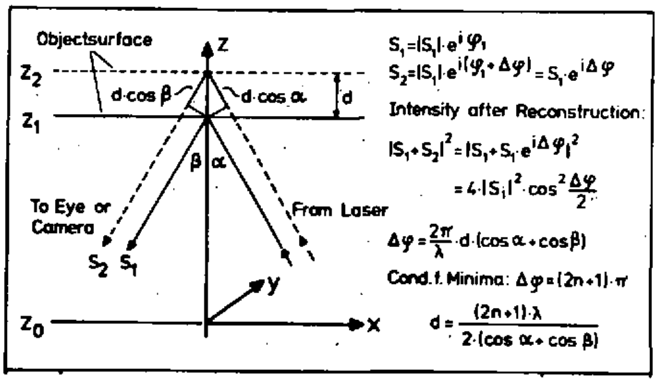


Figure 2

$\alpha$ and $\beta$ are the angles between the illumination and recording direction and the perpendicular line to the object surface respectively. The division of $\Delta d$ by the pulse distance $\Delta t$ gives the relative vibration velocity. It is proportional to the number of interference fringes per unit length (fringe density). If one wants to measure amplitudes it is necessary to know what vibration phases belong to the first and second pulse.

## 3. Applications

### 3.1 Mounting points of engines

For the diminution of transfer of solid body vibrations from the engine-gearbox combination into the passenger cell it is very important to find out the points of relatively small vibration in the engine shell, so that one can use these points for mounting the engine. This problem can be solved very well by holography because the interference pictures made by double pulsed holograms give an excellent survey over the vibration pattern. Figure 3 shows an interference picture of one side of a crankcase. The points of smallest interference fringe density concur with the points of greatest relative rest and are, from the acoustical point of view, preferable for mounting the engine in the car.

3.2 Vibration Transfer

Characteristic variations of the noise level of automobiles as a function of the speed of rotation are often caused by resonances of the carrier unit of the engine. In figure 4 the gearbox carrier shows a rotation around its own longitudinal axis which is not transferred to the car body. The hologram is made at 4020 revolutions per minute. The vibration pattern on the bottom of the car body is transferred from the front mounting points. At 4680 rpm we have quite a different vibration pattern (figure 5). The gearbox carrier gives torque vibrations which are transferred to the bottom of the car. They are responsible for the sound maximum measured at 4680 rpm.

Figure 3

Crankcase at 4300 rpm. Pulse distance $\Delta t$ = 200 $\mu s$.

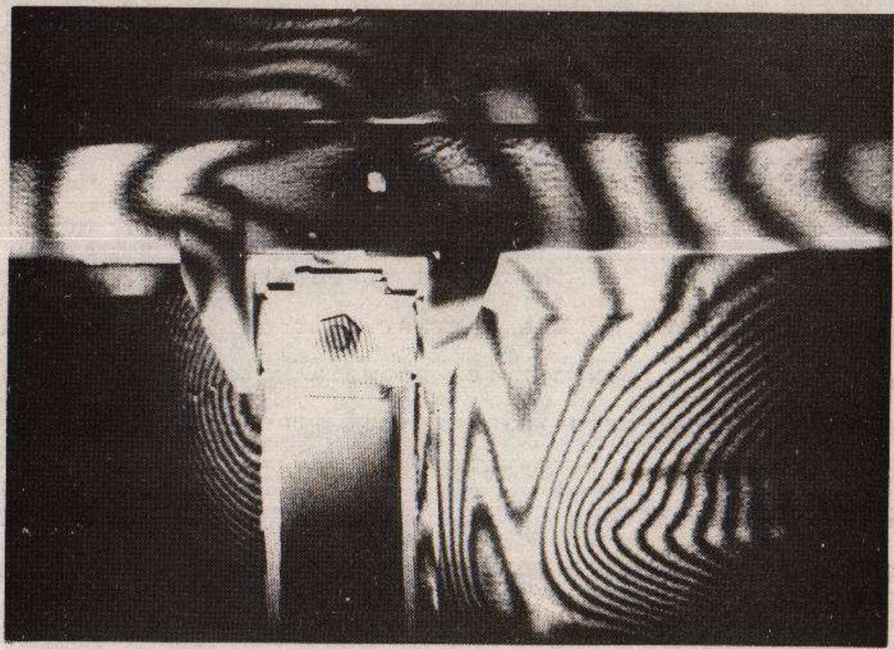

**Figure 4**
Gearbox carrier at 4020 rpm. Pulse distance $\Delta t$ = 1 ms.

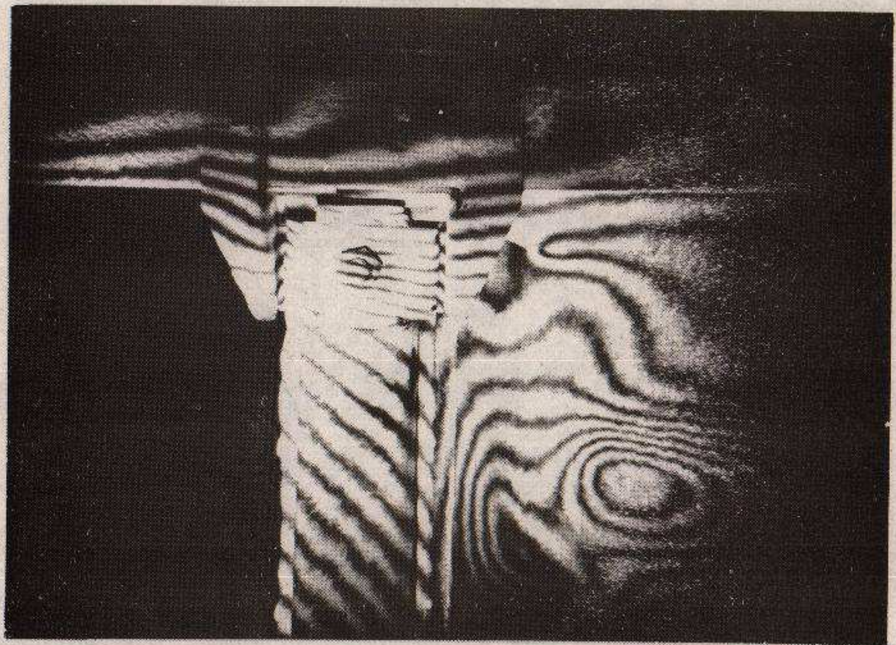

**Figure 5**
Gearbox carrier at 4680 rpm. Pulse distance $\Delta t$ = 1 ms.