CHAPTER I

ENGINE MOUNTS

Aside from its basic function as a structural member, the engine mount influences the engine installation as a whole. It governs the degree of accessibility of the engine and its accessories; the time required for the completion of the normal run of service duties; and time for removal and installation of the engine and mount. It also serves as an elastic structure primarily determining the vibration response in the airplane arising from the exciting forces in the power plant group. Because of the basic relationship between the mount and the remainder of the installation, the mount cannot receive too much attention at the time of its design. The mount should be mocked up and installed on an engine complete with all its accessories. Such procedure would permit consideration to be given to future requirements, such as the addition of other accessories, armamant, and the like, or the possibility of a change in the basic engine unit which might arise from the installation of other models of the same type engine.

All radial Wright Aircraft Engines are provided with the mounting bolt lugs arranged in a circle of sufficient diameter to permit the design of an engine mount ring which will allow for easy removal of the engine or its accessories. The installation drawings of individual model engines show the minimum inside diameter of the engine mount ring which can be used. It is to be noted that two ring sizes are provided for on the 9-cylinder Whirlwind Series engines. The larger ring is preferred for it permits the installation of certain special equipment that cannot be used with the smaller ring.

Where the engine is suspended from the mount ring by means of bolts through lugs on the ring, it is important that the faces of the lugs be in one plane so as not to distort the engine mount or produce undesirable deflections in the engine mount lug section.

With the size of the mount ring established, two other dimensions determine the design of the mount; namely, the distance from the ring to the firewall or mounting bay, and the disposition and number of attachment points at this point on the airplane structure. Installation drawings specify the space required for the removal of the most commonly used accessories. This is the minimum space that should be allowed between the engine and the firewall; however, any additional space provided will be advantageous in servicing the engine.

Following is a discussion of the most common types of mount structures used on current airplanes. The welded steel tubular mount is by far the most widely used. It is readily adaptable to all mount requirements, can be manufactured at a relatively low cost, and has established a good maintenance history. A monocoque, or semi-monocoque, cone shaped mount is desirable from a structural standpoint for attachment to a stressed skin nacelle. Its use is usually justifiable if the airplane is of such size as to preclude the possibility of servicing the engines from the ground. On such an airplane provision must be made in the structure for access to the engine from the inside of the ship through the wing and nacelle, or through the fuselage.

Figures 1, 2, 3, and 4 illustrate four commonly used types of engine mounts together with several rubber bushings for dampening vibration. Figure 1 illustrates a simple mount from a structural standpoint which is applicable to certain types of airplanes. It usually provides no rubber attachments. However, webbing is often used between the mount face and the engine but this seldom gives a smooth installation. The number of attaching points to the fuselage or nacelle can be varied to suit the design. Figure 2 illustrates a more conventional mount using four points of support at the attaching structure. It provides torsional elasticity by means of elongated rubber bushings mounted tangentially at the inner surface of the ring. Figure 3 illustrates a similar type mount but fitted with tube form rubber bushings

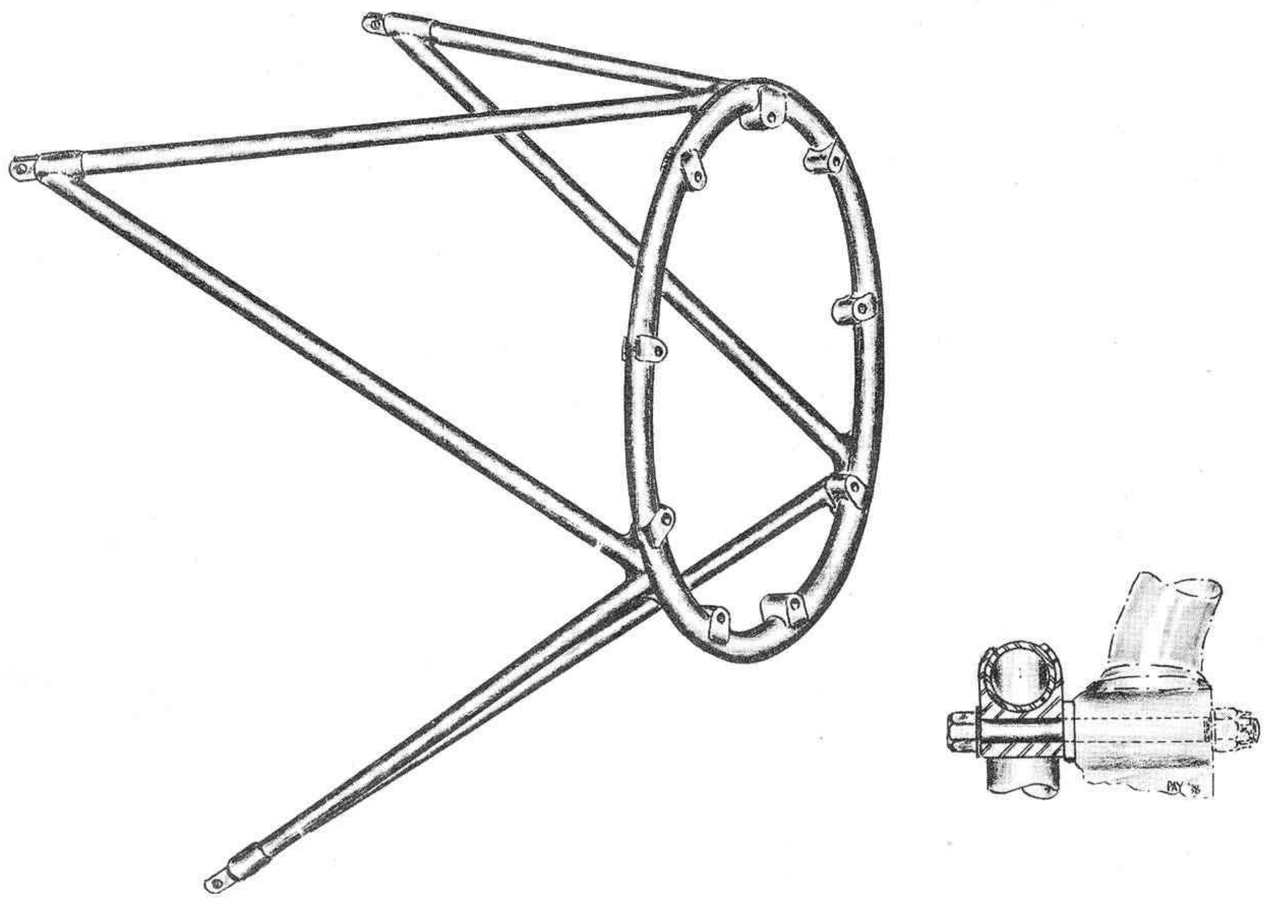

Figure 1

at the firewall attaching points. This type may or may not use the elongated type bushing as shown in Figure 2. Figures 4 and 5 illustrate a type of mount employing tube form bushings at each mount lug of the engine. This type provides a means of controlling the torsional resonant frequency to predetermined values. The resonant frequency in other modes of vibration may be calculated approximately and placed out of the cruising speed range. It is a distinct improvement from a vibration standpoint over the other type of mounts.

Mounts for large engines necessarily must be arranged with some sort of rubber bushings between the engine and mount attaching structure for the purpose of reducing vibration impulses to the airplane produced by exciting forces that are inherent in the power plant group. Psychological reaction to vibration is the major criterion of roughness and takes no account of airplane size but responds to absolute amplitude and frequency only. Therefore, large airplanes must have relatively less vibration response than small ones to produce acceptable vibration levels.

Before discussing the various types of flexible mounting systems, often referred to as vibration dampeners or shock mounts, it is well to investigate the various types or modes of motion which are subject to resonant vibration as excited by the power plant. They are:-

1. Angular oscillation of the engine about the crankshaft axis, usually called torsional vibration. This mode is excited by engine firing frequency, first order inertia torque variation, and half order gas torque variation.

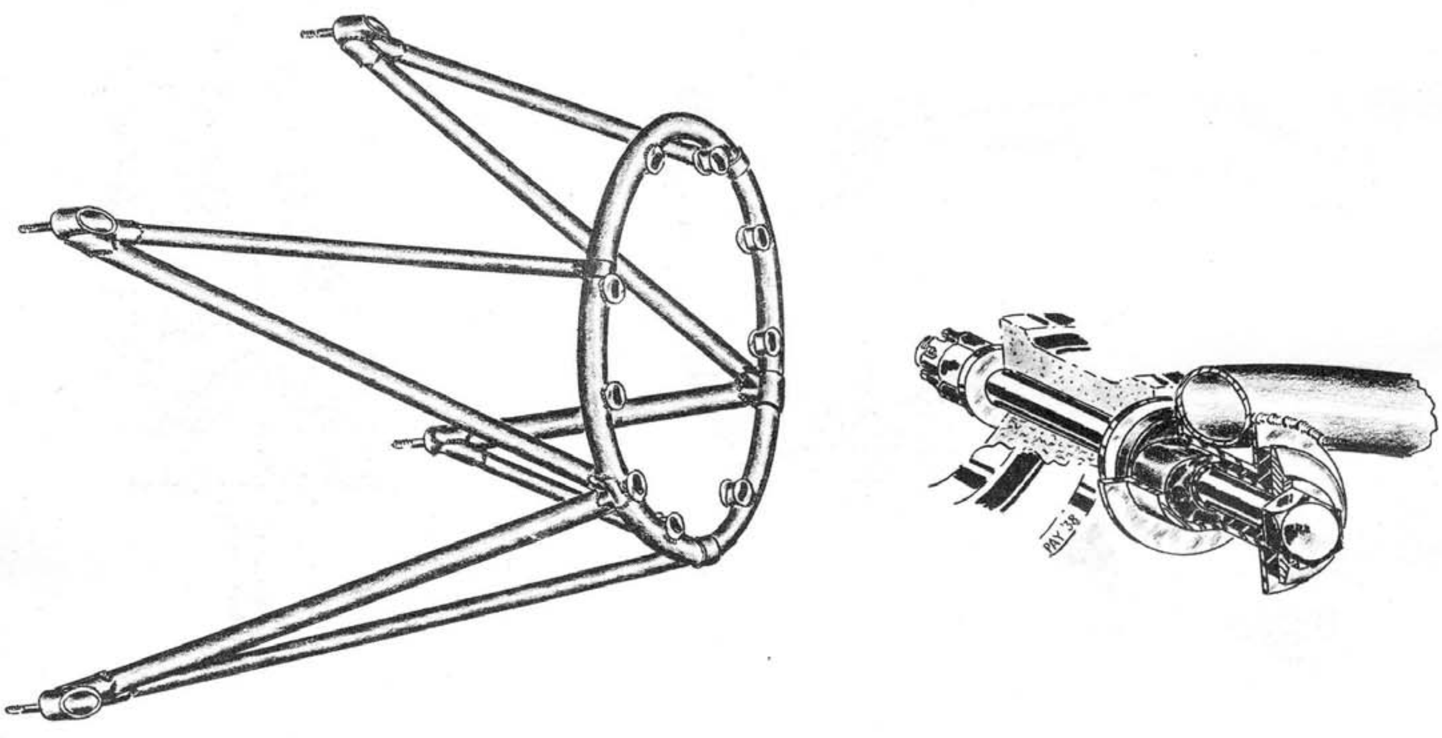

Figure 2

2. First mode bending of the fore and aft structural axis. This consists of cantilever type deflection and may occur in any plane or all planes as conical whirling about a node well to the rear of the engine. This node is susceptible to excitation from engine first and second order forces and propeller unbalance.

3. Second mode bending of the fore and aft structural axis. This consists of angular oscillation of the engine normal to the fore and aft axis. It may occur in any plane or all planes as conical whirling about a node ahead of the power plant center of gravity. This node is susceptible to excitation from engine first and second order couples (somewhat from forces) and propeller unbalance and pitch error.

4. Third and higher modes of bending of the structural axis wherein the propeller, engine, nacelle, wing section, and so on act as separate elastically connected bodies. These modes are susceptible to excitation from engine second order forces and couples, from firing order forces, and their harmonics. They are primarily inter-power plant vibrations and seldom appear beyond the wings.

If the elastic restraint is not symmetrical about the horizontal and vertical axes, the frequency of the modes will vary between the highest and the lowest, de-

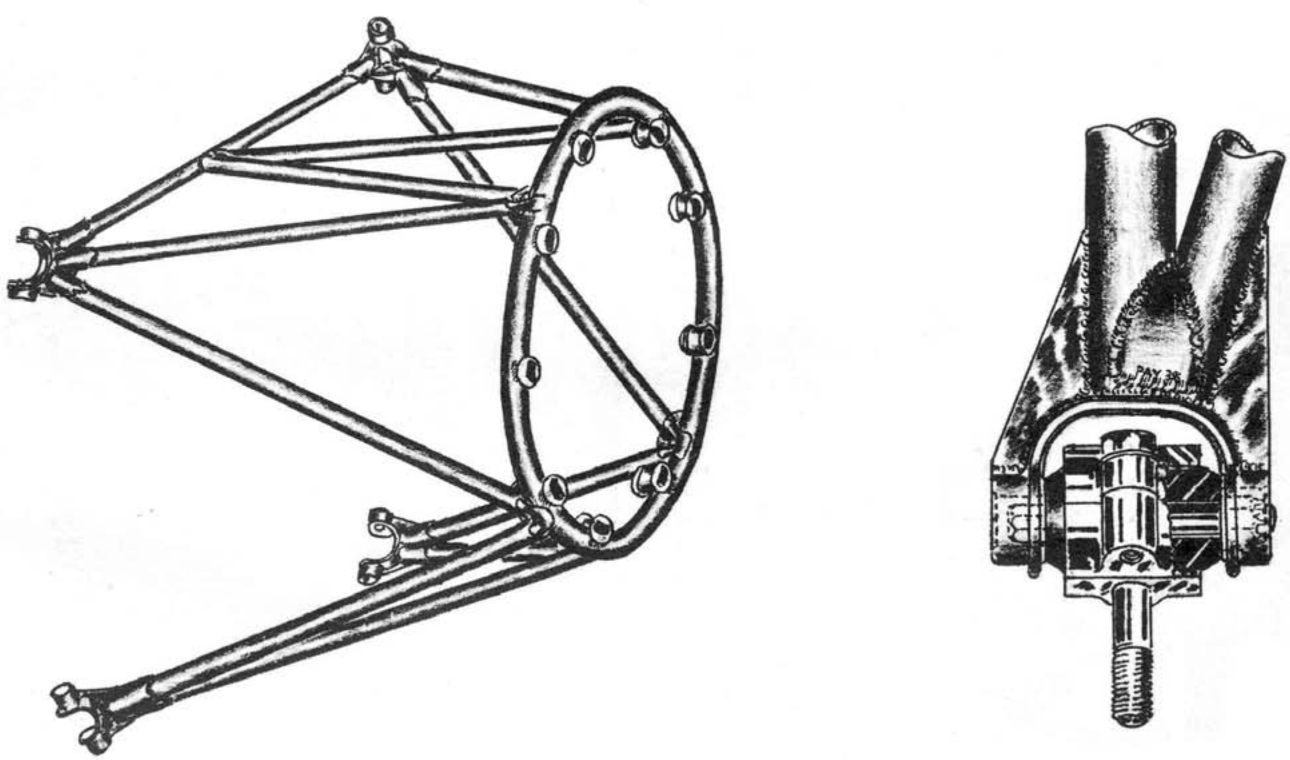

Figure 3

pending upon the plane of action thus providing a wide resonant response band which should be avoided.

The frequency of these modes can be definitely controlled and varied by the engine mount design. But, mode #4 is primarily dependent upon the natural frequency between the propeller and the engine which is a function of the moment of inertia of both units, the gyroscopic couple, and the bending stiffness of the propeller shaft and its housings. The engine mount also adds equivalent mass to the engine and lowers this frequency as determined with free suspension.

It has been customary to place the torsional resonant frequency response between 1000 and 1500 cycles per minute. This calls for a fairly stiff mount, which does not introduce undue complication in the plumbing and control installation because it limits the engine movement throughout the selected operating range including idle and warm-up. However, as the comfort requirements become more exacting, and the propeller gear ratios increase, and the cruising R.P.M. decreases, increase of flexibility incorporated in the engine mount is inevitable. Natural frequencies of 550 cycles per minute maximum in all modes are very desirable from the vibration

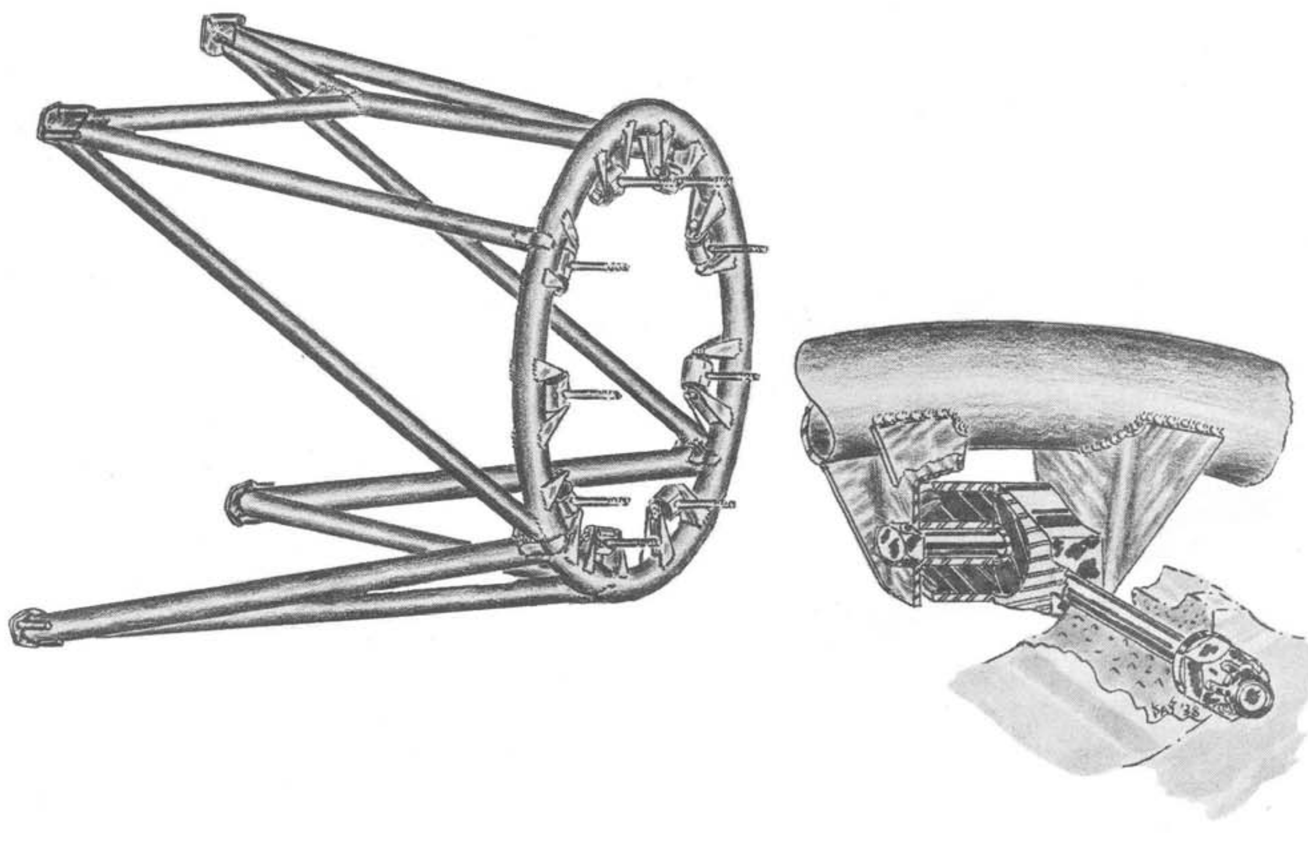

Figure 4

isolation standpoint. The automobile industry, in order to insure a vibrationless ride, has finally come to mountings with natural periods of around 250 cycles per minute in spite of the refinements made in engine balance proper. It is only a question of time before the aircraft industry will adopt some system equivalent to "floating power".

The first attempt at dampening vibration, arising from the power plant group, was the inserting of pieces of webbing such as woven brake lining between the engine mounting pads and the mount. This usually helped somewhat in small airplanes with low power in dampening the response arising from the inertia torque variations in the engine, and lowered the noise level created by the higher engine orders. This method has been improved upon by the use of the elongated rubber bushings, as shown in Figure 2, which have accomplished the same result but to a more noticeable degree in larger power plants. This type mounting can be designed for a natural torsional response frequency of as low as 1200 cycles per minute by varying the hardness of the

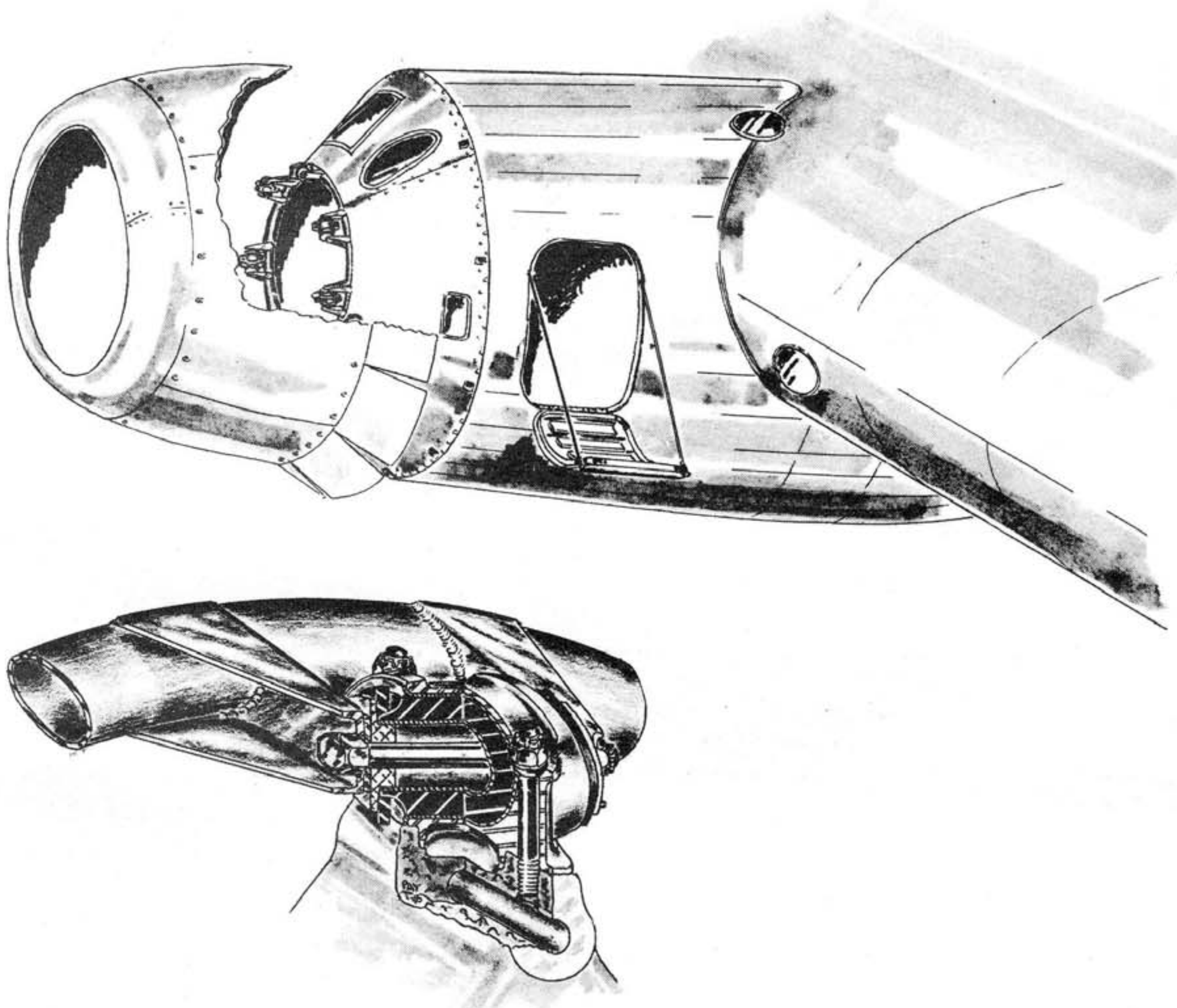

Figure 5

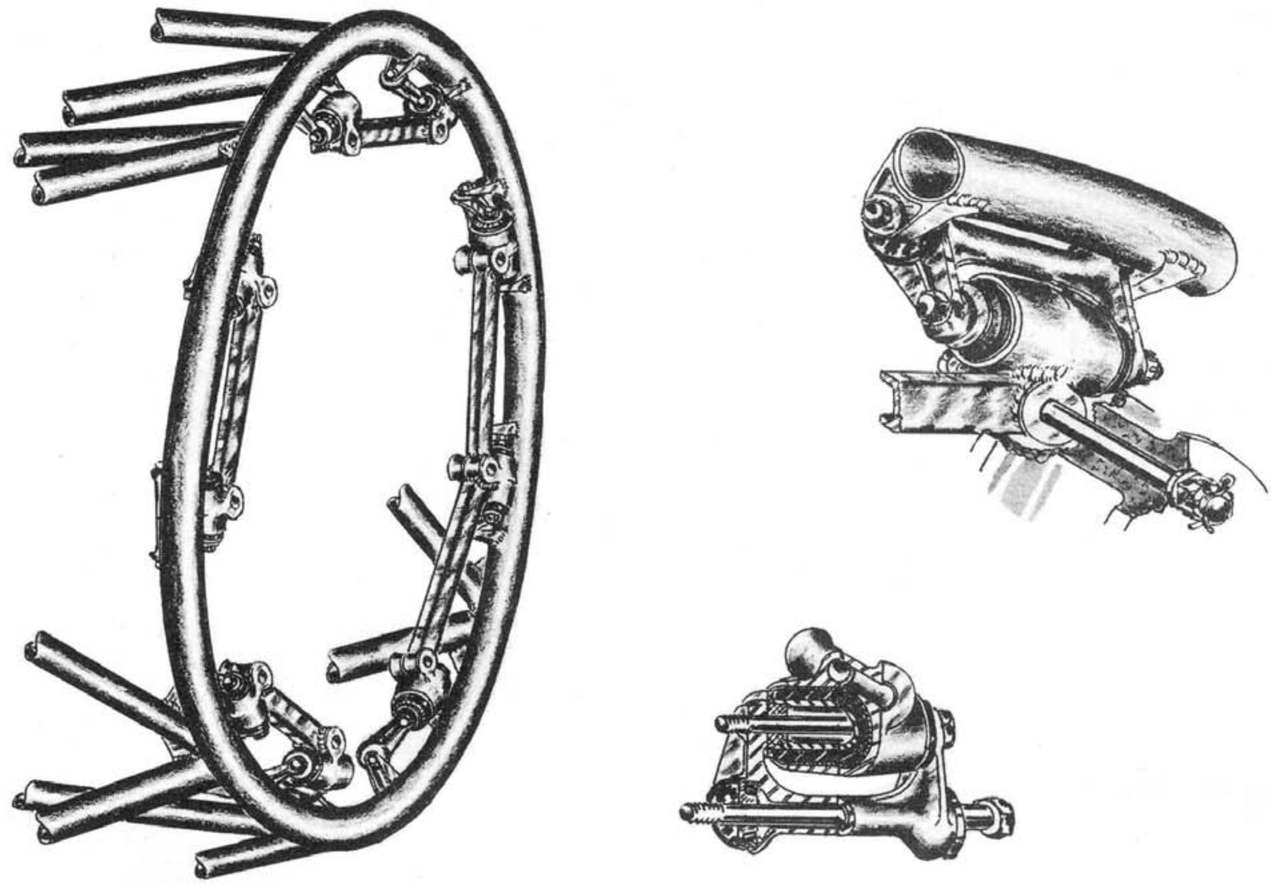

Figure 6

rubber, the size of the holes in the bushings, and the thickness of the washers. Another type mount which provides for a lower torsional frequency is that shown in Figures 4 and 6. By varying the hardness and quantity of rubber in the bushings, the natural torsional response frequency can be lowered to 600 cycles per minute.

A basic requirement when providing elasticity in the engine mount is to hold the engine in one position, fore and aft, firmly enough to permit satisfactory attachment of plumbing, controls, and cowling. The methods of using rubber bushings as illustrated in Figures 2, 3, and 4 all meet this requirement in the same manner, i.e., the fore and aft location of the engine is fixed by giving a fixed fore and aft location at each point of attachment. Thus the engine movement is also rigid angularly (yawing or pitching elasticity). This type of mount inherently has, therefore, a high frequency resonant response to exciting couples or forces applied away from the center of the mount ring. In all radial aircraft engines, particularly two-row radials, vibration exciting forces originate and appear as couples tending to produce pitch and yaw. To isolate vibration response to these couples in the operating range, the motor mount must contain an adequate amount of angular elasticity in pitch and yaw as well as torsional elasticity. A conventional mount with sufficient fore and aft elasticity to lower this response below the operating speeds has the objectionable feature of excessive drooping. This is due to the disposition of the mass ahead of the rubber bushings. This problem has been very effectively solved by the Wright Aeronautical Corporation in a type of mounting known as "Dynamic Suspension".

"Dynamic Suspension" is a practical means of complete vibration isolation and places all natural vibration frequencies of the power plant relative to the airplane well below all the exciting frequencies in the operating range. This is accomplished by an engine mounting system, as illustrated in Figure 6, which employs shackle type links attached to the engine mounting structure and joined to the engine by rubber bushings, so arranged as to provide the required elasticity in all directions, without objectionable elasticity in any direction. By use of "Dynamic Suspension" it is possible to place all of the natural response frequencies of the power plant below 500 cycles per minute. Manufacturers interested in the application of "Dynamic Suspension" are asked to communicate with the Field Engineering Department of the Wright Aeronautical Corporation for further details of its application.