11 Mechanical Design Considerations

11.1 Introduction

Once the type and size of engine have been determined, the number and disposition of the cylinders have to be decided. Very often the decision will be influenced by marketing and packaging considerations, as well as whether or not the engine needs to be manufactured with existing machinery.

The engine block and cylinder head are invariably cast, the main exception being the fabrications used for some large marine Diesel engines. The material is usually cast iron or an aluminium alloy. Cast iron is widely used since it is cheap and easy to cast; once the quenched outer surfaces have been penetrated it is also easy to machine. Aluminium alloys are more expensive but lighter, and are thus likely to gain in importance as designers seek to reduce vehicle weight.

Pistons are invariably made from an aluminium alloy, but in higher-output compression ignition engines the piston crown needs to be protected by either a cast iron or ceramic top. The piston rings are cast iron, sometimes with a chromium-plated finish. The valves are made from one or more alloy steels to ensure adequate life under their extreme operating conditions.

Engine bearings are invariably of the journal type with a forced lubrication system. To economise on the expensive bearing alloys, thin-wall or shell-type bearings are used; these have a thin layer of bearing metal on a strip steel backing. These bearings can easily be produced in two halves, making assembly and replacement of all the crankshaft bearings (main and big-end) very simple. For the more lightly loaded bearings the need for separate bearing materials can be eliminated by careful design. The use of roller or ball bearings in crankshafts is limited because of the ensuing need for a built-up crankshaft; the only common application is in some motorcycle engines.
The role of the lubricant is not just confined to lubrication. The oil also acts as a coolant (especially in some air-cooled engines), as well as neutralising the effects of the corrosive combustion products.

Only an outline of the main mechanical design considerations can be given here. Further information can be found in the SAE publications, and books such as those detailed in Baker (1979), Newton et al. (1983) and Taylor (1985b).

11.2 The disposition and number of the cylinders

The main constraints influencing the number and disposition of the cylinders are:

(1) the number of cylinders needed to produce a steady output
(2) the minimum swept volume for efficient combustion (say 400 cm$^3$)
(3) the number and disposition of cylinders for satisfactory balancing.

The most common engine types are: the straight or in-line, the ‘V’ (with various included angles), and the horizontally opposed — see figure 11.1.

![Common engine arrangements](image)

(a) (b) (c)

Figure 11.1 Common engine arrangements. (a) In-line; (b) ‘V’; (c) horizontally opposed

‘V’ engines form a very compact power unit; a more compact arrangement is the ‘H’ configuration (in effect two horizontally opposed engines with the crankshafts geared together), but this is an expensive and complicated arrangement that has had limited use. Whatever the arrangement, it is unusual to have more than six or eight cylinders in a row because torsional vibrations in the crankshaft then become much more troublesome. In multi-cylinder engine configurations other than the in-line format, it is advantageous if a crankpin can be used for a connecting-rod to each bank of cylinders. This makes the crankshaft simpler, reduces the