Chapter 1. Introduction to machine dynamics

1.1 Basic concepts and definitions

*Working processes and machines.* In the long run, contemporary industry leads to the fulfilment of a wide range of working processes. The majority of them are connected with the treatment of raw material (stock) and the conversion of stock into semi-finished or completed products; these are known as *manufacturing processes*. Manufacturing processes are accompanied by *materials handling*, coupled with the transfer of raw material or semi-finished products to the workplace and of the final products to their place of use, and by *energy processes* that include the conversion of energy into the most convenient form for use. *Data processing* is significant in contemporary technology, ensuring that process control operations, design requirements, technical documentation etc., are all satisfied.

Many working processes are carried out with the help of some form of mechanical movements. For example, to operate on materials in a machine tool it is necessary to move stock and tools; to handle raw materials and finished products requires them to be moved mechanically, and to convert heat energy into electrical energy it is necessary to turn the shafts of steam turbines and generators, etc. Human beings can produce a variety of mechanical movements, which means that they can perform some working processes manually. However, in contemporary industry, most working processes that produce mechanical movements are performed by *machines*.

![Fig.1.1. Schematic diagram for a single driver machine.](image)

We shall use the name *machine* for systems intended to cause the mechanical movement necessary to perform any working process. Depending on the way the procedure is carried out, a machine can be a manufacturing device, or a
mechanical handling devices, or an energy converter or data processing system.

**Machine structure.** We will analyse the dynamics of machines which are complex systems, incorporating several sub-systems. These sub-systems will be called the functional units of the machines. Functional units include drivers, mechanical systems and driver control systems. Complex machines that consist of several functional units are usually called machine sets. Fig. 1.1 shows schematically the simplest form of machine set. The schematic arrangement of a multiple driver machine is shown in Fig. 1.2.

To obtain mechanical motion in machines it is always necessary to convert some form of energy into work. Such conversion occurs directly in the driver. Depending on the form of energy conversion we can have electrical, hydraulic or pneumatic drivers or heat engines.

The process of energy transformation is controlled by the input, \( u \), to the driver (see Fig. 1.1). In electrical motors the control variable is the electrical voltage supplied to the circuit windings (in DC motors), or the supply frequency (in asynchronous motors). In hydraulic motors, control involves changing the pump output to the motor or the position of the throttle valve that regulates the delivery of working fluid. In internal combustion engines, control consists of an arrangement to change the amount of fuel supplied to the combustion chamber.

![Fig.1.2. Schematic diagram for a multiple driver machine.](image)

The output of a driver usually appears in the form either of rotary motion or reciprocating straight-line motion. The driver output variable, \( q \) is the generalised coordinate by which this is defined.

The transformation of the simple motion from the driver output into motion of the working components of the machine is carried out by mechanisms. The number of inputs to a mechanical system is usually equal to the number of drivers; this is known as the number of degrees of mobility of the machine. The inputs to the mechanical system are the generalised driver output variables \( q_1, q_2, \ldots, q_m \), and the outputs are the positions \( x_1, \ldots, x_n \) of the machine working components. The transformation of motion occurring in the mechanical system is characterised by the position functions

\[
x_s = \Pi_s(q_1, \ldots, q_m) \quad (s = 1, \ldots, n)
\]

During the working process the active forces \( P_s \ (s = 1, \ldots, n) \) are produced