Chapter 8
Rotor Balancing in Turbochargers

8.1 Reasons for the Rotor Balancing

In the following section, we focus only on the rotor balancing in turbochargers and not in the industrial turbomachines because we can find them in [1], [4], [6], and [10].

Production process of the compressor wheel and turbine shaft causes an initial unbalance where the mass center does not lie in the geometrical axis of the compressor wheel or turbine shaft. Excessively large unbalance force and moment induce large amplitudes of the rotor response, leading to the bearing wear, rub contact, and seizure of the journal and bearings and as well as the compressor, turbine wheels and their housings. Additionally, the rotor unbalance generates unbalance whistle that has the synchronous frequency order (1X) of the rotor frequency. The unbalance whistle is one of the undesirable airborne noises in the automotive turbochargers.

There are two possibilities of producing the turbocharger rotor: either production of the rotor without or with the rotor balancing. If we choose the first one without the rotor balancing, the production of the compressor wheel and turbine shaft must be highly precise, so that the mass-center eccentricity of the rotor is in the order of a few microns (∼10^-6 m) from its geometric axis. It leads to large deficient producing rates and therefore very high producing cost. Notice that producing cost is one of the most important competition key of products in the industry, and “cost, cost cut, and cost breakdown” always accompanies the products on their lifetimes. Therefore, the economical way is producing turbochargers with the rotor balancing, at which the production process is less precise. Despite the less precise production process, the rotor arrives at an acceptable residual unbalance after the balancing procedure that brings the mass center of the rotor possibly close to the rotational geometric axis.

8.2 Kinds of Rotor Balancing

There are two kinds of the rotor balancing in the automotive turbochargers:

- Low-speed balancing (called shop balancing) is used in the rigid rotors at a low balancing speed up to 3,400 rpm, depending on the balancing machine types, to reduce the initial unbalance caused by the production process. Generally, the
whole rotor is not balanced at the shop balancing, but only the compressor wheel and turbine shaft are separately balanced at the rigid state with the low-speed balancing. Hence, it is also named single part balancing. The low-speed balancing is generally carried out with two balancing planes at the nose and back face of the wheel. The goal of this balancing is to reduce the unbalanced force and moment to minimize the induced unbalanced excitations and therefore to prevent the radial bearings from damages due to contact rub and seizure between the journal and bearings caused by the excessive rotor unbalances.

- High-speed balancing (called trim balancing) is applied to the flexible rotors at a high balancing speed (generally above the first critical speed) at which the rotor deflects in the lateral direction due to large unbalance forces and moments. Besides the initial unbalance due to production, an additional unbalance is resulted from mounting the compressor wheel on turbine shaft and as well as the deformed rotor at high rotor speeds during the operation. Hence, it leads to the unbalanced whistle; therefore, the additional unbalance must be removed by the trim balancing. The high-speed balancing is carried out with two balancing planes at the screw-nut of the compressor wheel and the hub surface between the blades at the compressor wheel outlet. The purpose of the trim balancing is only to reduce the unbalance whistle during the operation at high rotor speeds, especially in passenger vehicles. Generally, one omits the trim balancing in the turbochargers of commercial vehicles and industrial applications unless the customers explicitly require.

### 8.3 Two-Plane Low-Speed Balancing of a Rigid Rotor

The production of the compressor wheel and turbine shaft induces the static, couple, and dynamic unbalances. The static unbalance occurs when the polar mass-inertia axis differs from the rotational axis by an eccentricity $\varepsilon$. On the contrary, the couple unbalance occurs when the polar mass-inertia axis differs from the rotational axis by an angle $\alpha$; however, they intersect each other at the mass center G.

![Fig. 8.1](a) Static unbalance; (b) Couple unbalance