LOW-PRESSURE COMPRESSOR AERODYNAMIC DESIGN

Jérôme Lépine

Snecma Moteurs – France

In this chapter, the design process of a low-pressure compressor also called booster for turbofan engines, will be described. At a first time, the summary of objectives will allow us to set the global design process. Then, we will focus on the two main steps of the design that are the setting of the throughflow and the drawing of the blades. Finally, after having introduced the concept of compressor matching, we will spend some time on the multi-stage aerodynamic analysis and on technology that both require a special care for low-pressure compressor (LPC) design.

Turbojet engine low-pressure compressor combines the objectives and processes of a fan and of a booster so that this article will mainly focus on booster design with a view to avoid repetitions of the fan design section.

1. Design objectives

Designing a booster could be seen as less of a technical challenge than designing a fan. In fact, the dimensioning part of the low-pressure spool is the fan for mechanical stresses and for acoustics. However, the aerodynamic is far more difficult in a booster because of the necessity to optimize the performances of several stages at the same time with a main flow greatly perturbed by secondary flows and by the interaction with technology. The global objectives, which have much in common with fan design, are presented in the compressor map by figure 1. The main items are found (performances, operability, environment friendliness and security) but the design points on which they apply are slightly different.

1.1. Cruising speed

Most of the time of a flight is spent at cruising speed, therefore the main target for this speed is to minimize the specific fuel consumption (SFC) and, as a consequence, to optimize the efficiency of each component of the engine and in particular of the booster. Moreover, because the cruise point shifts on the map as the weight of the airplane diminishes during the flight, the design must guaranty the highest level of efficiency on a whole range of speed. To achieve a high level of performances, each stage of the compressor must have a high efficiency but it is also necessary for the whole compressor to be perfectly matched to take full advantage of the stages performances. From an environmental point of view, improving performances reduces the SFC which is also a way to reduce NO_X and CO_2 emissions.

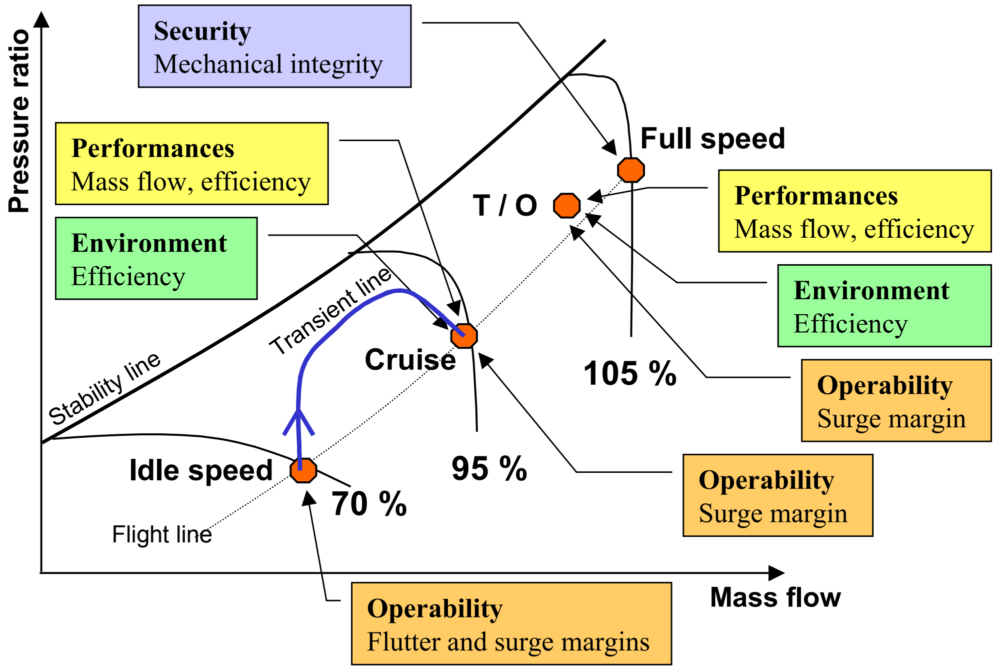

Fig. 1 - Compressor map and design objectives

Surge margin characterizes the capability of the booster to keep on providing the compression whatever fluctuations of the flow or instabilities occur during the flight. Indeed, any modification of the inlet conditions are likely to modify the operating point of the compressor. The modifications may come from many different events like a cross-wind gust or like the ingestion by the engine of ice or birds or also like the crossing of clouds or of a rainy area. As it as been explained in the first chapter *General considerations*, surge is too dangerous for the engine manufacturer to take any risk with it.

From a mechanical point of view, the whole range of cruising speed must be free from any mode that could increase blade fatigue due to force response or flutter and that could lead to a blade failure. This is a matter of security because a blade-out triggers the engine stoppage but it is also a matter of money because in such a case the cost of repair is about the cost of a new engine and because the life expectancy of the blades sets the time between two shop visits and, as a consequence, the cost of maintenance.