CHAPTER 1. PROBLEM STATEMENT

Additive manufacturing techniques have marked a milestone due to the innovative nature of the idea compared to traditional manufacturing by subtractive methods and due to its enormous versatility, spreading rapidly to many industrial sectors. Today it is easy to find additive manufacturing applications in very diverse fields, from automotive or aeronautics to biomedical or defence engineering.

Thermoplastic polymers for 3D printing are the most widely used today, but technological evolution has made it possible to employ additive manufacturing techniques in other families of materials such as metals, hydrogels and soft materials of biomedical use, biological tissues or even energetic materials, such as solid propellants and explosives. Within thermoplastic polymers, polyamides (in particular polyamide 12) are one of the most widely used families, both for their thermal properties that facilitate the manufacturing process and for the final mechanical properties obtained.

There are many issues related to the new additive manufacturing techniques that require a great research effort. One of the most relevant issues is the optimisation of the manufacturing parameters to achieve the highest quality and the best performance of the products and components manufactured in this way. However, this is not the research topic of this doctoral thesis, more focused on mechanical behaviour.

From the mechanical point of view, there are some issues that need to advance in knowledge. On the one hand, there is the possible anisotropic response of materials that are characterised by presenting a structure of layers that have been successively deposited. Even supposing that within each layer the behaviour is isotropic, it is quite reasonable to think of different responses in the direction parallel and perpendicular to the deposition of the material, that is, a transversely isotropic behaviour. On the other hand, the manufacturing process itself is prone to inducing a population of characteristic defects, such as unmolten particles or porosity, which can affect the mechanical response and the integrity of the components manufactured this way, especially in the fracture and fatigue behaviours. It is true that all manufacturing processes can have families of characteristic defects and, therefore, it is necessary to assess the response of additively manufactured materials compared to those manufactured by other techniques.

Many works can be found in the scientific literature that study the mechanical properties of polymers processed via additive manufacturing techniques. The most common is to find results from uniaxial tensile tests and comparative studies on the response of materials manufactured by 3D printing and injection or compression moulding. Studies focused on fracture characterization are scarcer, in line with some difficulties inherent to polymers in applying Fracture Mechanics methodologies: influence of the notch sharpening process, viscoelasticity, etc.

However, where there is a great lack of results is in the response to cycling loads, that is, in the fatigue behaviour. There are several reasons behind this situation in the literature: firstly, the fatigue characterization of polymeric materials is very time-consuming because they have to be tested at low frequencies, usually around one hertz, to avoid thermal damage; secondly, the knowledge of the fatigue behaviour of polymers is far from that achieved in the field of metals because the physical mechanisms responsible of damage nucleation and propagation of fatigue cracks are much less well defined.

This does not mean, obviously, that in the field of metals the response to fatigue is a solved and closed problem. The problem of short cracks continues to be the object of intense study and the need remains open to improve the unified description of short and long cracks, with approaches similar to that proposed by the Kitagawa-Takahashi diagrams. The fatigue behaviour of notched components continues to need solutions, despite the enormous effort made in this field by renowned researchers such as Neuber, Glinka or Lazzarin. Probabilistic approaches are another front that, step by step, is providing increasingly satisfactory results.

In this situation, this doctoral thesis is proposed, which aims to characterise the fatigue behaviour of polyamide 12 manufactured by selective laser sintering and to compare its behaviour with the same material manufactured by injection moulding. The approach is clearly experimental, trying to provide information from a careful testing program that includes uniaxial tensile tests, fracture mechanics tests and fatigue tests in specimens prepared in different orientations with long and short cracks.