In this work an unconstrained analysis of the detection and quantitative characterization limits of lock-in infrared thermography applied to sub-surface flat flaws, so-called delaminations, is addressed. With this goal, aiming to avoid material property or experimental parameter dependant conclusions, a dimensionless numerical model has been developed. This formulation allows a noticeable reduction of the, often, large and correlated number of parameters which govern the associated thermal diffusion problem to 4 dimensionless parameters, without lack of generality. After experimentally validating this model with calibrated planar buried flaws, the dimensionless numerical calculations have been used to feed a global sensitivity analysis. As a result, a detailed discussion is performed towards the quantitative identification of cross-correlations together with maximum sensitivity and predominancy parametric ranges of the obtained dimensionless parameters. In conclusion, the developed work provides a valuable general experimental guideline for an optimized thermographic quantitative characterization of delaminations in materials.