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A NEW METHOD FOR ZONAL LES – URANS COMPUTATIONS WITH EXCHANGE OF INFORMATION BETWEEN DIFFERENT CODES

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In the design and analysis of gas turbines, Computational Fluid Dynamics (CFD) is nowadays widely used to analyze separately components of the engine, employing specialized flow solvers for every component. When the flow in turbine is studied, RANS and URANS approaches are usually employed. On the other hand, when the flow in a combustion chamber is analyzed, a LES approach demonstrates to be more accurate and the only way to properly handle flame instabilities, which are one of the main problems affecting modern lean combustors. Nowadays, the interest of analyzing gas turbines beyond component level has triggered the need to couple different highly specialized codes based on LES and RANS/URANS to accurately represent the mutual interaction between turbine a combustor: in fact, technologically interesting phenomena such as the hot steaks migrating from the combustor and impinging on turbine blades and the combustion instabilities cannot be properly analyzed by means of separated analyses [1].
To handle the different temporal and spatial scales of the solvers, coupled approaches have been introduced by Shluter et al. for incompressible solvers [2] (also used by von Terzi et al. [3]) and Morata for compressible solvers [4]. These are not satisfactory for the reproduction of the time-dependent influence of a downstream URANS domain on the upstream one. The current work discusses a new approach suitable for the coupling of compressible LES and URANS codes, in which the correct time-dependent influence of the URANS downstream on the upstream LES solution (and vice-versa) is guaranteed.

A scheme of the new implemented approach is shown in Fig.1 (a). This is based on the theory of the characteristic waves [5]. For a subsonic flow, four characteristic waves (one pressure wave, the entropy and vorticity waves) leave the outlet of the upstream domain, whilst one pressure wave enters from the external field. The entering wave is specified to be almost zero by means of a relaxed approach when the outlet is imposed as anechoic without coupling, according to the Navier-Stokes Characteristic Boundary Conditions (NSCBC) treatment [5]. On the other hand, at the inlet of the upstream domain one characteristic wave will leave, while the remaining four waves are entering from the external field.
To get a proper influence of the upstream solution on the downstream and vice-versa, the two computations are solved at the same time, and boundary conditions are passed between the upstream and the downstream domains (referred in this paper as domain 1 and domain 2

respectively). When the computation starts, the value of ***L1*** is calculated at the inlet of domain 2, and used to get the time-dependent outlet boundary condition for the LES solver at domain 1, together with ***L2, L3, L4*** and ***L5*** calculated within the LES domain. The LES solver computes the solution for domain 1 until the URANS time step is reached. After that, properly filtered values of waves ***L2, L3, L4*** and ***L5*** calculated at the outlet of domain 1 are used to get the inlet conditions for domain 2 after being properly filtered, together with the value of the pressure wave ***L1*** coming from the inlet of the second domain. The URANS solver can then calculate one time step, and the described process can be repeated. The exchange of information between codes is assessed by the external software OpenPALM.
Results obtained with the new analyzed approach are deeply compared to a more classical one based on the work of Morata for compressible codes (shown in Fig.1 (b)) pointing out advantages and weak points. The validation and comparison of the procedures has been carried out for laminar configurations in which a critical mutual influence of domains 2 and 1 is expected. In the end, a turbulent duct is studied using the developed LES-URANS coupled simulation with the same method, to discuss in more depth the approach applied to a turbulent test case. The coupling procedure based on the characteristic waves demonstrates to be encouraging for what concerns the low spurious reflection of fluctuations at the outlet of domain 1 and the time-dependent influence of domain 2 on 1.

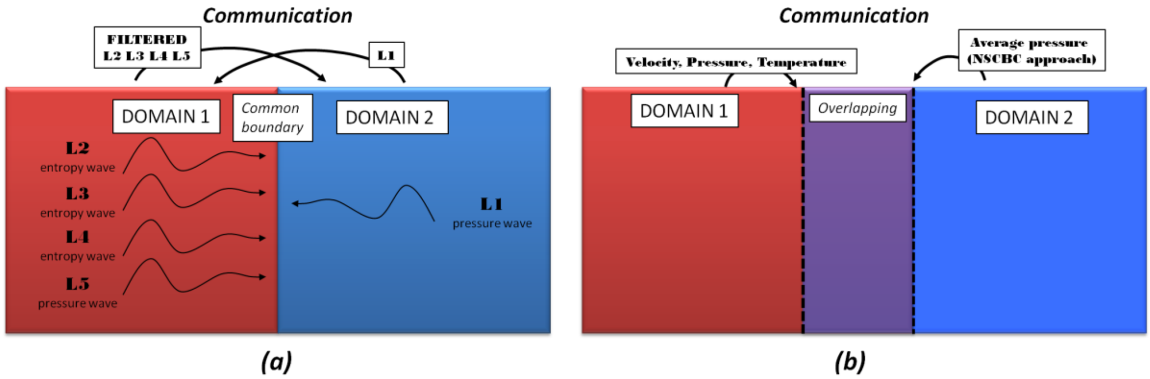

Fig. 1 Scheme of the coupling in study, based on the passage of characteristic waves between the two domains (a) and approach based on the overlapping between domains and passage of variables (b).

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