The paper could be published subject to the following revisions:

1) What are the computational and experimental uncertainties? The discrepancies between CFD and the experiment may be within the range of these uncertainties.

2) The effect of the grid size should be superimposed on the comparisons.

3) A comparison of the spectra against the spectra of the Taylor-Green vortex should be presented; see Drikakis et al. Simulation of Transition and Turbulence-Decay in Taylor-Green Vortex, Journal of Turbulence, 8, 1, 1-12, 2007.

The paper could be published subject to the above revisions.

Referee #2 (Comments to Both Author and Editor):

The paper investigated experimentally and numerically the flow around a circular cylinder at Reynolds number (Re) of 4815. The investigation used Particle Image Velocimetry (PIV) and the SST Detached-Eddy Simulation (DES) turbulence model as the experimental and numerical methodologies. The article focused on validating the experimental and CFD results using Proper-Orthogonal Decomposition (POD) analysis. The paper is clearly written, but wordy. Its aim is unoriginal, and the paper has some inconclusive/wrong conclusions. Thus, the reviewer recommends the rejection of paper. Below are the major and minor issues.

Major issues:
- The introduction is weak, and lacks an aim:
-- The introduction does not show what current literature lack.
-- Validating CFD against experimental results cannot be an aim for a journal paper. P.3 last paragraph of section I.
-- P.3 last paragraph of section I, " ... allowed us to validate the predicted coherent flow structures and their energies, leading to a validated fully three-dimensional (3D) numerical POD results.' Circular cylinder coherent flow has been investigated extensively by many previous studies.

- Experimental methodology lacks important information:
-- How were the PIV raw data processed to determine the velocity fields?
-- Please clearly provide the resulting vector displacement, which might be dependent on the number of paths and overlapping, if either was used in data processing.
-- Uncertainty.
-- Stereo-PIV camera orientation.
-- Free-stream pixel shift, between consecutive frames.

-- Please confirm that single frame PIV was used. If double frame please provide the time-shift.

- What is the maximum and average Y+ value?

- CFD validation should be done, with previous studies, for forces, separation angle and local mean pressure coefficient.

- By visually inspecting the PIV results, it is clear that many of the contours seem to be shifted slightly up, instead of being symmetric/antisymmetric around the x-axis. E.g., Figs. 11(a), 13(a). That might be resulting of incorrect rotation or translation, and should be rectified by correcting the PIV calculated velocity flow field.

- Major concerns with analysis:
-- PoM2 analysis only used the x-velocity. That is a major issue, as the y-velocity has important impact on flow shedding, more significant than that of the x-velocity. Ignoring y-velocity misrepresent flow physics at PoM2.
-- The analysis based itself on validating CFD POD against experimental one. However, shedding is expected to validate even for not highly accurate data, and its validation does not eliminate the existence of errors. For example, if the CFD experience different quantitative forces than previously reported in literature, POD validation is unlikely to show that. For cylinders, the POD most two energetic modes (responsible for shedding) have much higher energy contribution than subsequent modes. Thus, the data need to be really bad for them to fail validation.
-- Fig. 9 is expected to have very close distribution for PoM1 and PoM2. That is not shown, which is suspected to be resulting from neglecting y-velocity in PoM2.
-- P.21, "However, for the higher modes, the turbulence causes a transfer from periodicity to a chaotic behavior in the modes chronoses." That is inconclusive. Higher modes may need more snapshots for convergence, higher sampling frequency or other. Also, modes 15 and 16 do not show chaotic. They may be reflective of different coherent motions.
-- P.22, "toposes colored by the spanwise vorticity component contours". Contours are of the spanwise vorticity, and are NOT colored by spanwise vorticity. The second implies that u or v spatial POD contours are illustrated, and that they are colored by vorticity, which is not the case. Please correct that throughout the paper.
-- "laminar-like" has been frequently used throughout the discussions. The flow is turbulent, and the POD modes are representative of different flow phenomena. By reconstructing selected number of modes, coherent component of the turbulent flow is formed, not laminar flow.
-- P.25, "Furthermore, it is to be expected that also all the higher modes on PoM2 will exhibit dynamics similar to the first mode as they add further layers of time-wise stationary perturbances to reconstruct the original flow spatial characteristics." The reviewer strongly disagrees with this statement. First two POD modes must be different

than the rest of the modes, as they represent shedding. Which should still have noticeable influence for x/D<4.
-- From the reviewer rough calculations, the article used data of 140 shedding cycles. Which are not expected to be enough for POD to have high order modes (>2) converged. That is reflected by examining the absence of symmetric/antisymmetric for modes 3 and higher.
-- P.25 + Fig.13, Comments on mode 3 contours should consider that the mode is expected to be antisymmetric. The absence of that is expected to be resulting from not using enough snapshots. Thus the comment of "the simulated topos is less pronounced and the structures are less connected." is invalid considering that the error shown from antisymmetric absence is more prominent.
-- P.25 + Fig.26, what is meant by "POD analysis of the laminar von Karman vortex street". Present study is at Re=4815, fully turbulent wake. Have laminar data at much lower Re have been used?
-- P.25, "... purely the two-dimensional data from PoM1", cylinder wake at Re=4815 is 3D not 2D. Thus, it cannot be "purely" 2D. Wake is 2D in mean.
-- P.26 + Fig.13(c), "... meaning that some level of regular oscillations at the flow second harmonics is to be expected ...". It is not surprising that oscillations would happen at the harmonics; however, more peaks are shown at other frequencies, not only the 2nd harmonic. Why was the discussion was selective?
-- P.25-27, The third POD mode spectra is usually referred to as the "Slow-Drift" or "Shift-Mode". For example Kindree2018(https://doi.org/10.1007/s00348-018-2641-x), Abdelhady2021(https://doi.org/10.1063/5.0038925), Bourgeois2013(https://doi.org/10.1017/jfm.2013.494)
-- Fig.14 and all other PoM2 figures + Fig.20 and associated discussions. Totally strange that the POD mode 3 and higher have u changing sign along the span. That might be resulting from end effects occurring at very low frequency or mode that POD mathematically captures to be similar to the slow-drift. Although the paper, later, commented on oblique shedding; the existence of such contours, even if due to oblique shedding misrepresent cylinder airwake.
-- P.28 + Fig.16, does not the mismatch between PIV and CFD an indication of something incorrect?
-- P.29 + Fig.17 + ref[23], "... seventh PoM1 mode topos seems somehow similar to the third 2D laminar POD mode, see[23]...". It is inappropriate to compare ref.[23] Fig.2b x-velocity spatial POD contours to the present study vorticity. (Next statement is minor issue) Also, the spatial dimension of the field used for POD would affect the spatial modes. Obviously, [23] includes flow fields for D/x<0.5 (mode 1 of [23])
-- P.37, "The first 10 modes contain 65% of the flow kinetic energy and seem to represent the regular laminar-like flow structures." The first 10 modes represent the most energetic turbulent modes not laminar flow. These modes could be used to represent the coherent turbulent flow.
-- P.38, "To obtain a qualitatively accurate approximation of the fine flow structures even

farther streamwise from the cylinder and to eliminate the unphysical formations, it is necessary to use around 3000 POD modes." The reviewer strongly disagree. Low TKE modes may be unphysical. In order to correctly capture low modes high sampling frequency, spatial resolution and long flow time are usually required. Which are usually not fulfilled by PIV and CFD (except DNS).

Minor issues:
- P.2L3, it is not a good practice to cite many references, without elaborating on their findings.

- P.3, "designed to bring detailed data on flow dynamics." Detailed data is very generic and redundant. Time-resolved PIV provide unsteady flow field data, and planes at which PIV is done have to be selected.

- Why stereo-PIV was done for PoM2? Despite that only x-velocity was analyzed for PoM2

- P.5 (end of it), no need to cite OpenFOAM

- It is not clear if the CFD mesh span dimension is the same as the tunnel or simply has 6D. Please clarify.

- P.11 (close to end), "... a temporally coherent spatial structure ...". Strictly speaking for $j >> 1$, the flow represented is expected to be incoherent component of the flow, using Reynolds triple decomposition.

- No need to redefine parameters previously defined. E.g., x_r got defined on P.5 and P.14

- How was the turbulent kinetic energy calculated? Some references divide by 2 and others by 3. Was the CFD turbulent kinetic energy based on the three velocity components or only two? Please make that clear for section V.A

- P.20, what is the "standard POD"? Is that snapshot? classical? SVD?

- P.21, "Because of the similar structure of the coupled modes, we analyze and compare only one mode from the pair. In particular, we concentrate on the modes 1, 3, 5, and 7." Please provide basis on which higher modes are coupled or similar, or a reference.

- Unit of spectra amplitude need to be in SI base units. Please correct that for all figures. It is better to non-dimensionalize the frequency and amplitude.

- What is the Q-criterion threshold?

- Typos:
-- P.2, "shadding"
-- P.49, "apmlitudes"

- The reviewer believe that the appendix is redundant, considering that the paper should not be a tutorial.

- The paper is wordy in general. Below are few examples:
-- P.3, "The problem at hand consists of the cross-flow around a circular cylinder."
-- P.20, "Again a comparison is performed on the both planes of measurement ..."
-- P.20, "... we compare squared singular values of the matrix Y defined in (11), which characterize the turbulence kinetic energy of the system captured by the corresponding mode for both the measured and computed data." Simply, compare turbulent kinetic energy contribution.
-- P.21, "captured ... planes of measurement ..."
-- "chronos spectra" is repeatedly used. "Chronos" is redundant.
-- "Still, examining purely the two-dimensional data from PoM1."
-- P.26, "Similarly to the analysis of the first POD mode, ... both the PIV and CFD data."

- References:
-- [47] please make "Piv" and "les" uppercase
-- [61] use uppercase for "svd"
-- [67] "two-dimensional"
-- [68] "2D"