CAPÍTULO VI

CONCLUSÕES

As primeiras simulações realizadas utilizando os códigos *LAYER2* e *CIL3D* não foram bem-sucedidas diante do objetivo de analisar fisicamente escoamentos do tipo jato livre. Entretanto, estas simulações foram essenciais como forma de aprendizado, fornecendo conclusões importantes para orientação da continuidade do trabalho. A conclusão fundamental foi com relação à ordem do esquema numérico utilizada no código computacional. Os resultados obtidos através dos dois códigos *LAYER2* e *CIL3D*, os quais empregam esquemas numéricos de 2ª ordem, não permitiram a identificação de *estruturas coerentes* e apresentaram tensores de Reynolds super-preditos com relação a dados experimentais. Foi constatado desta forma, que esquemas de 2ª ordem não são suficientes para SGE e SND de jatos livres, comprovando o que pôde ser verificado em outros trabalhos (Glaze e Frankel, 2003; Uzun, 2003; Freund, 2001). Vale ressaltar também que o modelo de Smarogisky certamente promove a dissipação das instabilidades no regime de transição, prejudicando a visualização das estruturas.

Diante do insucesso da utilização de códigos com esquemas de 2ª ordem para simulação do jato, optou-se pelo desenvolvimento de um código pseudo-espectral para realização deste estudo. Embora tal método permita apenas a análise temporal do jato, foi possível verificar que esta análise é similar aos estágios apresentados pelos jatos espaciais, conforme verificado também por outros autores (Basu e Narasimha, 1999; Mathew e Basu, 2000). Embora não haja possibilidade de uma comparação quantitativa com dados experimentais, foi possível verificar a semelhança entre as estruturas presentes em jatos temporais e experimentais e identificar as fases de evolução do jato espacial em diferentes instantes da evolução do jato temporal.

Estruturas típicas do escoamento do jato puderam ser evidenciadas: instabilidades primárias do tipo Kelvin-Helmholtz, vórtices toroidais, vórtices helicoidais, filamentos longitudinais, e ainda fenômenos tais como emparelhamento, transição, espalhamento em direções transversais, e degeneração em turbulência desenvolvida. Os espectros de energia permitiram verificar a proximidade da região inercial do jato à inclinação de -5/3, conforme

apresentado pela literatura. A região de decaimento do jato também pôde ser identificada, apresentando acúmulo de energia nos casos em que a resolução espacial não foi suficiente para resolver todas as escalas do escoamento. A relevância do número de modos de Fourier para obtenção de resultados satisfatórios foi também comprovada.

A possibilidade de controle do jato, de grande interesse prático, foi constatada ao se verificar a formação de diferentes estruturas, diferentes taxas de espalhamento com expansão preferencial em determinada direção, transição mais rápida à turbulência em função do tipo de perturbação sugerida. O estudo realizado possibilitou ainda associar o surgimento de modos lineares, sub-harmônicos e azimutais assimétricos ao tipo de perturbação imposta. Este conhecimento é extremamente importante para que tais resultados possam ser obtidos na prática de controle de jatos, ao utilizar-se alto-falantes e atuadores para gerar aqueles mesmos modos fisicamente.

Desta forma, o método pseudo-espectral utilizado mostrou-se eficiente para a análise física do escoamento do jato livre a Reynolds 1600. Embora, os escoamentos com aplicações práticas apresentem números de Reynolds superiores aos estudados, a mesma metodologia pode ser aplicada. Entretanto, faz-se necessária a otimização do código *SPECTRAL* através da implementação de modelos de turbulência e uso de esquemas compactos de alta ordem na direção do escoamento, o que permitirá a simulação de jatos em desenvolvimento espacial e a comparação mais exata com dados experimentais.

A seguir, algumas perspectivas para a continuidade do trabalho serão enumeradas:

- Implementação de modelagem sub-malha da turbulência;
- Utilização de esquemas compactos de alta-ordem na direção do escoamento, para simulação de jatos em desenvolvimento espacial;
- Inserção de modelos de combustão.

CAPÍTULO VII

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