

Interactive Fluid Dynamics Visualization

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ABSTRACT

In this paper we describe TurboPump, an interactive visualization application that enables domain scientists to explore fluid dynamics turbulence models. The size of the data prevents the datasets to be loaded, thus data processing is discussed. By using standard visualization techniques, like streamlines and vector fields, it was possible to develop an interactive visualization tool to explore the data. Furthermore, the visualization application is detailed and explained and the observations and findings concluded.

KEYWORDS: Interactive visualization, centrifugal pump, fluid dynamics, 2011 visualization contest.

INDEX TERMS: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism; I.3.8 [Computer Graphics]: Applications

1 INTRODUCTION

The visualization of fluid dynamics is a non-trivial task that requires deep knowledge of the data to be visualized. The contest data is consisted of three data sets of the same centrifugal pump, each obtained with a different turbulence model. The selected models are the DES, SST and SAS for the same centrifugal pump and consist of 80 time steps that compromise a full rotation [3]. Each model's size is around 160GB so the total size for all three models is 500GB of raw data. Objective of the contest is to develop a visualization tool that will enable the domain scientists to identify instabilities and vortices. Those instabilities and vortices have huge impact in the turbomachinery design, because they potentially cause structural vibrations of the pump [1][2].

In this paper we describe TurboPump, an interactive visualization application that tackles this problem. TurboPump was developed as a class project for the CS524 - Visualization and Visual Analytics II - class at the University of Illinois at Chicago.

2 DATA PROCESSING

To gain a better understanding of the data, Paraview [4] was used to take a first look at the instabilities and vortices for each model. After identifying possible problematic areas, the data was pre-processed so that it can be fully loaded into the memory. We loaded some of the time steps into Paraview and explored possible seeding locations for streamline generation. After experimentation we observed that the instabilities develop near the blades of the pump, so we decided that the best locations to place the seeding spots were the center of the pump as well as near the blades. The dots show the seeding points (Figure 7). Random seeding was used.

Another observation that we made was that the pump structure was extremely detailed and existed in every time step of each model. This redundancy was not needed, so we extracted the

structure and saved it to a file. After extracting the structure and creating the geometry of the pump, to further reduce the triangles needed to draw the pump, we decimated the triangles and smoothed out the result.

The velocity vector field was visualized using a hedgehog (0). Since the vector field was very dense, by using random seeding ten thousand points were selected. For the pressure visualization seventy isosurfaces were created. This pre-processing has reduced the amount of data to be loaded into the visualization application from 160GB for each model to 2GB.

3 TURBOPUMP VISUALIZATION

For the User Interface the QT 4.7.0 framework was used, while for the 3D visualization the Visualization Toolkit 5.6.1 (VTK). The application can be used to explore the instabilities and vortices of the fluid dynamics that develop in the same centrifugal pump (0).

3.1 Main Window

The "Main Window" area is being used to gain insights and answer questions regarding the instabilities of the centrifugal pump. Initially the structure of the pump is visible, but it can be hidden using the "Control Area". Moreover when the structure is hidden, the rotor blades are visible as a reference point to where the instabilities develop. The visualized data can be zoomed in or out, panned, as well as rotated to give the researchers the ability to investigate the data.

3.2 Centrifugal Pump Window

When investigating the data, it is of great importance to map areas of interest with the related areas of the pump. Since the instabilities and vortices develop inside the pump, they are obstructed when the structure of the pump is visible. Therefore in the top right corner of the application a view of the centrifugal pump is always visible. This view is synchronized with the main window view, so that panning and zooming affects the camera.

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3.3 Control Area

The “Control Area” (Figure 11) is used to affect the view of the visualization. Figure 1 shows the description of the individual buttons.

Streamlines Center	Shows the streamlines when the seeding point is the center of the pump
Streamlines Blade 1	Shows the streamlines when the seeding point is a point near the rotor blades of the pump
Streamlines Blade 2	Shows the streamlines when the seeding point is a point near the rotor blades of the pump
Pressure	Shows the pressure isosurfaces
Velocities	Shows the water velocities inside the pump for the selected model
Show Pump	Shows the structure of the pump
Play / Slider / Reset	Control the animation – time steps for the selected model
DES / SAS / SST Radio Buttons	Loads the relevant model into the visualization area

Figure 1. Description of the available actions

4 FINDINGS

The pre-processing of the initial dataset has reduced the data into a feasible size that can be loaded into the memory of an application, without the use of a cluster or super-computer. This allowed us to create an interactive visualization that domain scientists can use to explore fluid turbulence model datasets and identify instabilities and vortices. By using streamlines, it is immediately clear that the vortices in all three models appear between the blades of the pump (Figure 4, Figure 7, Figure 8). In the SST model the vortices have a smaller radius and hence are more difficult to identify. By switching the streamline colour mode to “Kinetic Energy”, we can observe that:

- vortices in the DES and SST models (see difference between Figure 9 and Figure 10) have a higher Kinetic Energy than in the SAS model
- it is easier to identify a vortex and instabilities in the DES and SAS models because of the new color scheme (Figure 9)

Moreover when the chosen color scheme is “Velocity” the color coding of the streamlines (Figure 3) as well as of the hedgehog (Figure 5) shows that the greatest velocity is at the outskirts of the pump. Finally, when the pressure isosurfaces are enabled, a fluctuation of the fluid pressure can be seen near the center of the pump (Figure 6).

5 CONCLUSION

By using pre-processed data it was feasible to have a dataset that can be loaded and manipulated in real time. Streamlines proved to be the best method to find instabilities and vortices for each model, while the hedgehog gives an overall snapshot of the fluid velocity inside the pump. The pressure isosurfaces does not seem to help identify the unstable areas. The ability to interact with the

application and load different models provides flexibility and portability and allows the observation of the phenomena that develop over time.

REFERENCES

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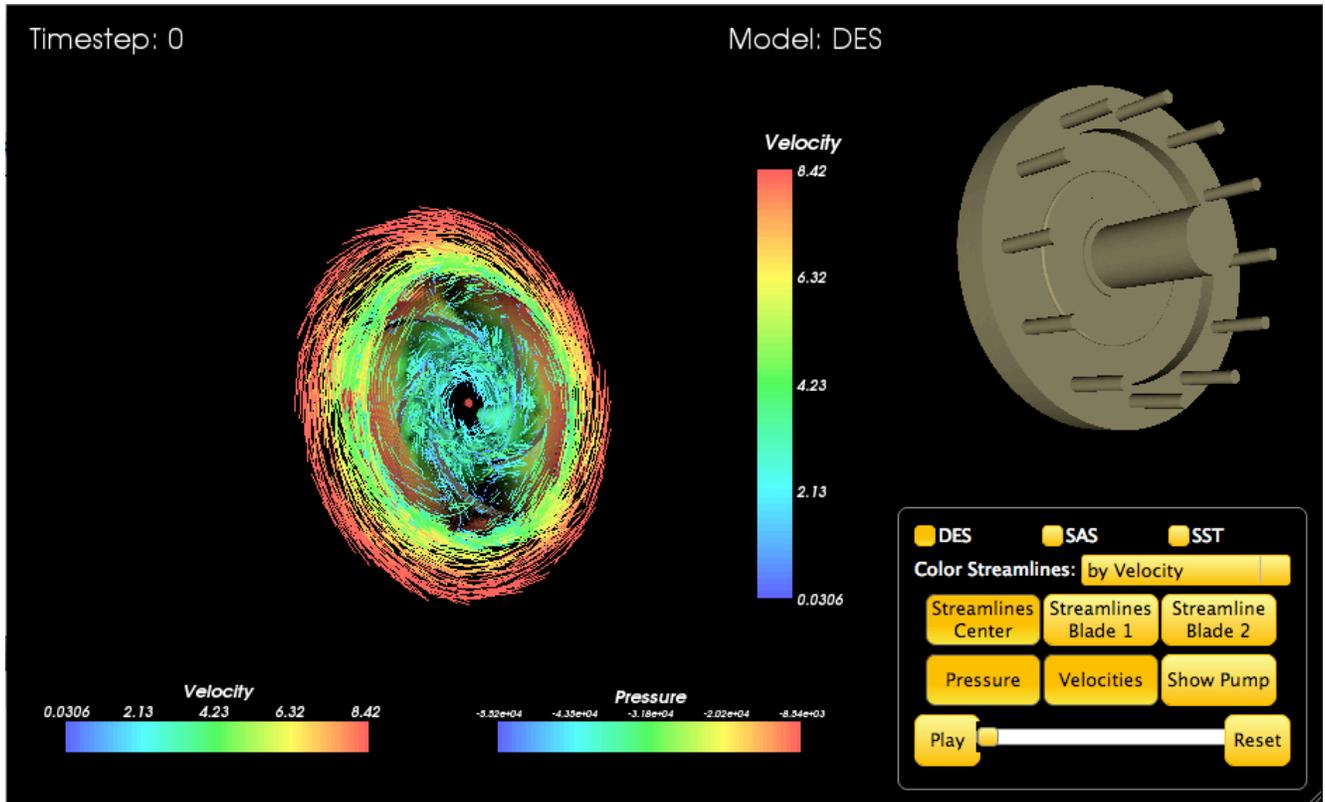


Figure 2. The TurboPump Visualization

Timestep: 0

Model: DES

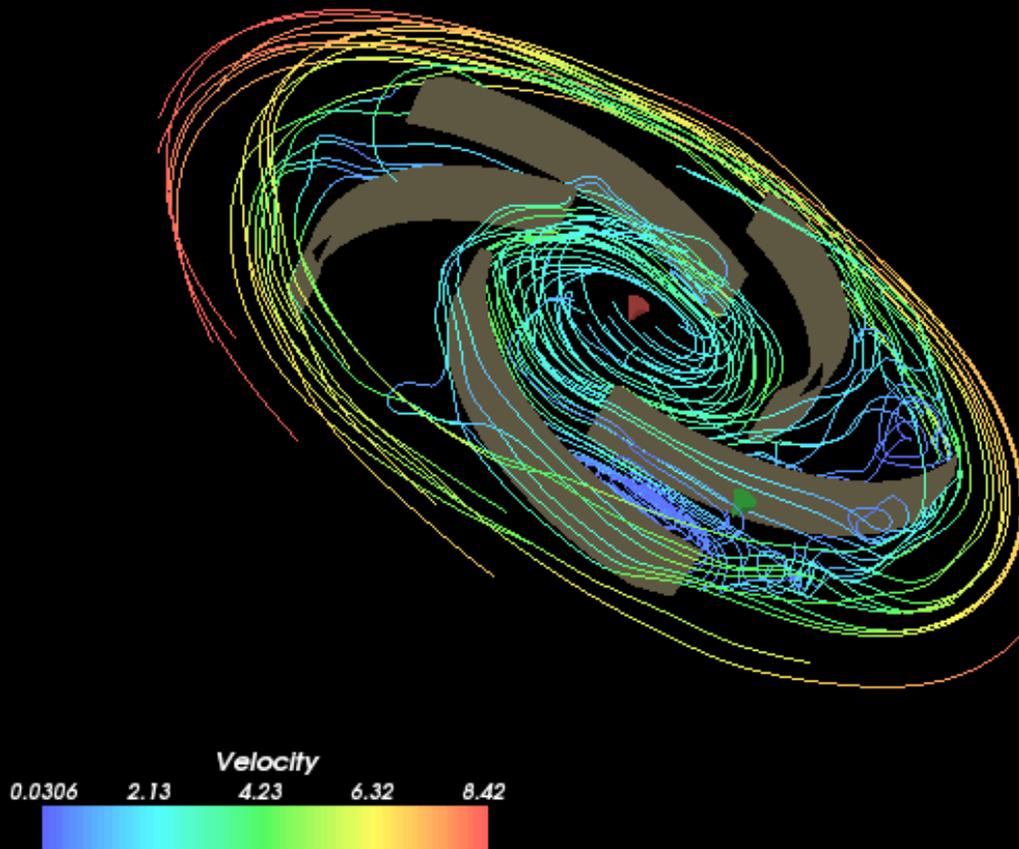


Figure 3. Looking at the streamlines. Coloring based on velocity.

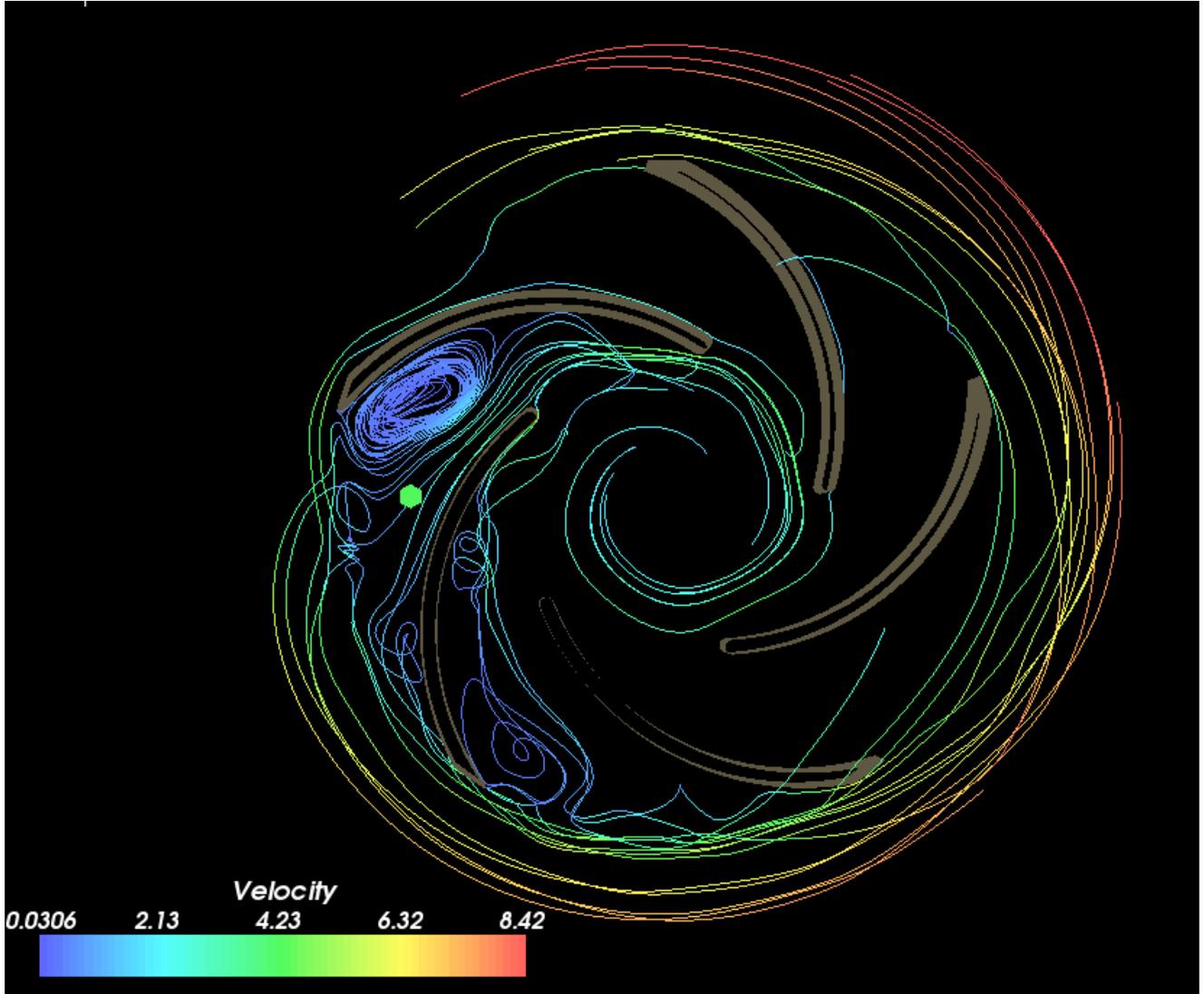


Figure 4. Identification of a vortex using streamlines. Model: DES.

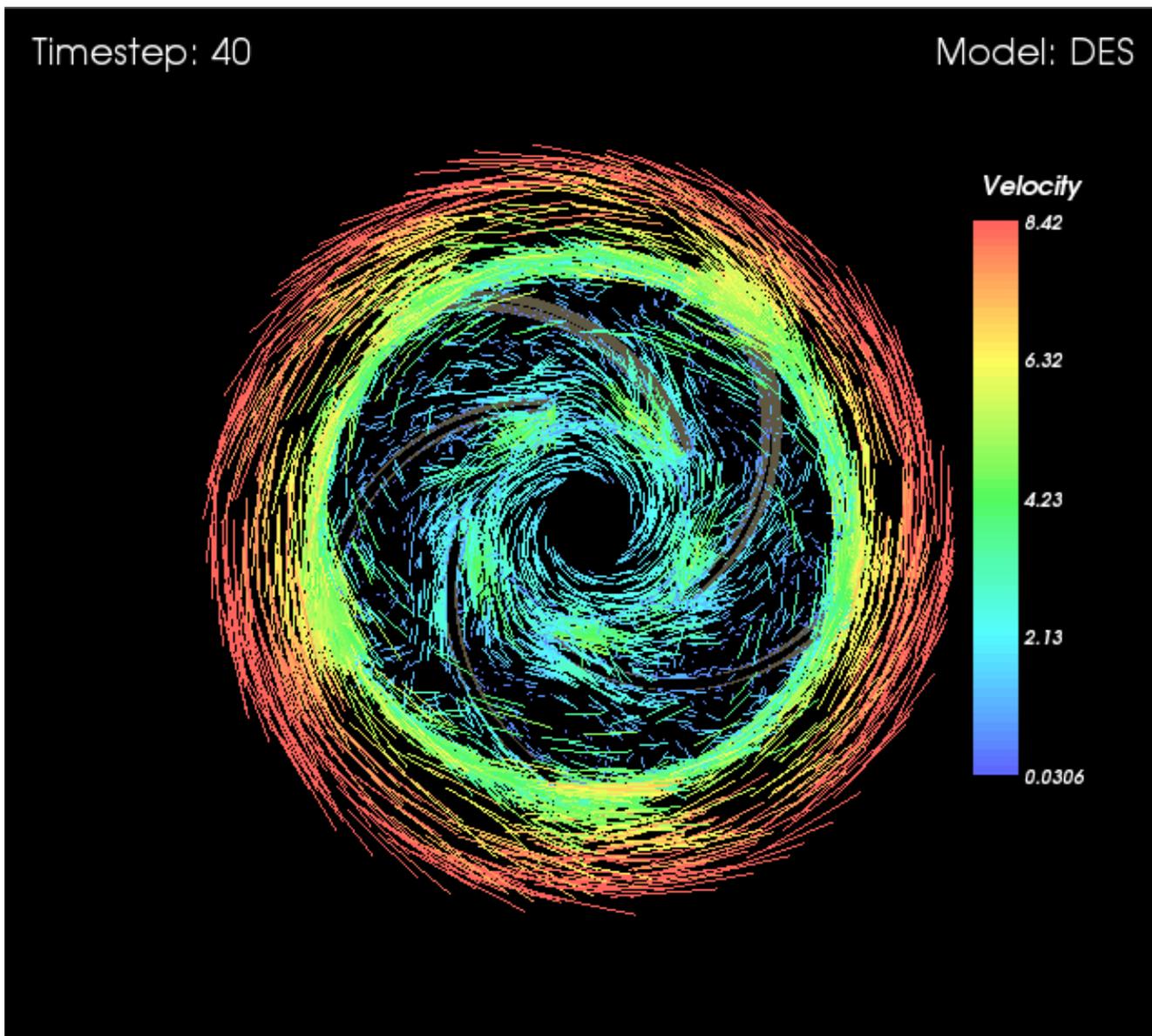


Figure 5. Velocity vector field using hedgehog representation

Timestep: 0

Model: SAS

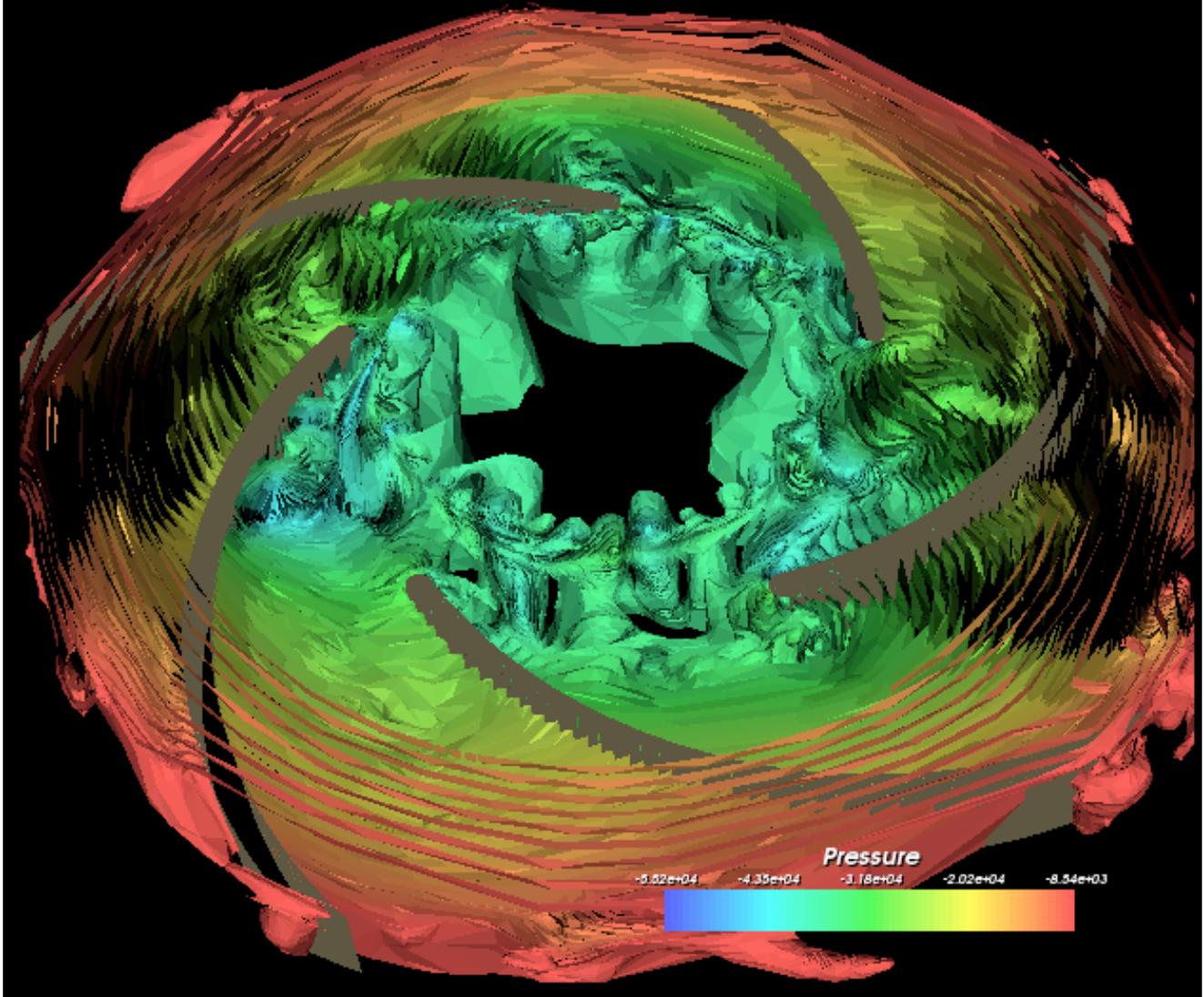


Figure 6. Pressure isosurfaces

Timestep: 52

Model: SAS

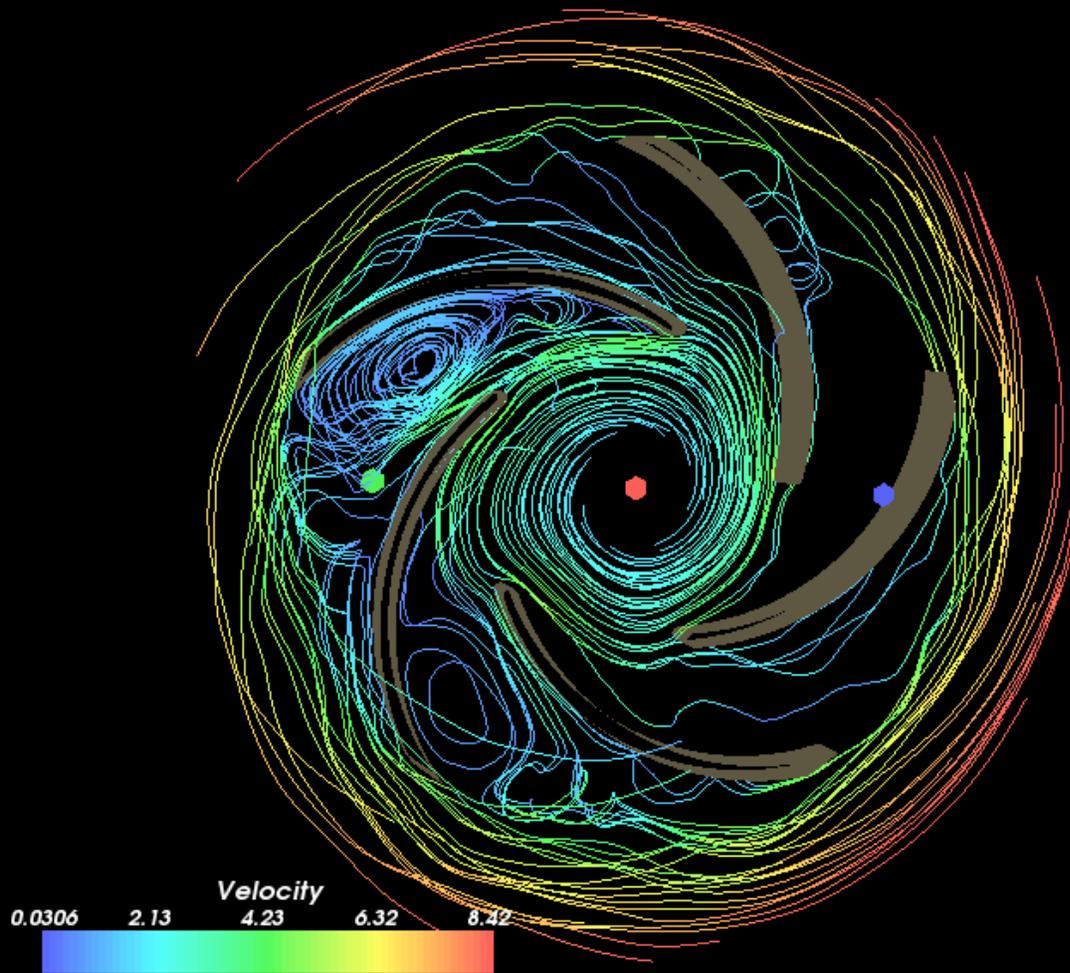


Figure 7. Vortices in the SAS model. Coloring by velocities

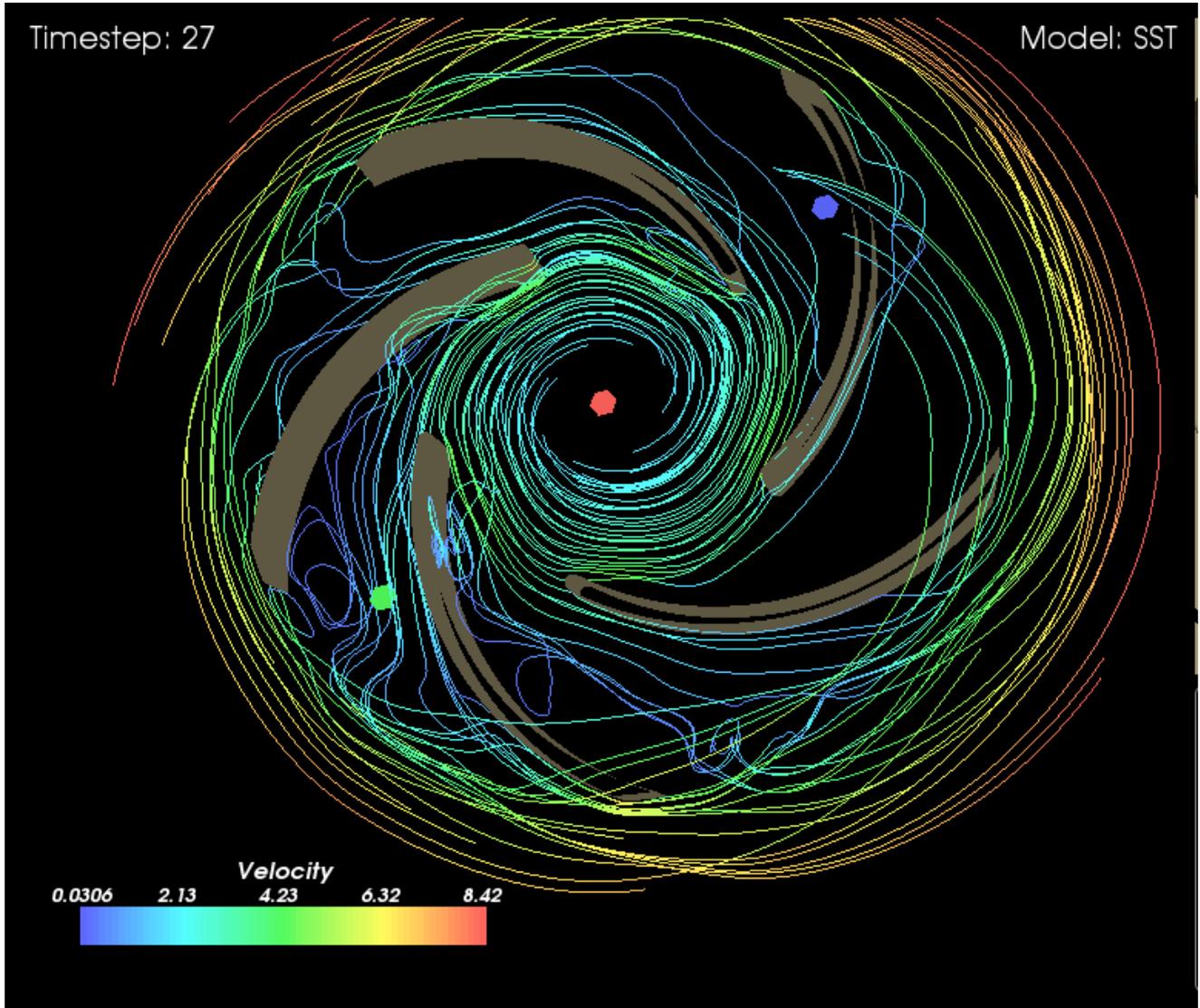


Figure 8. Vortices in the SST model. Coloring by velocities

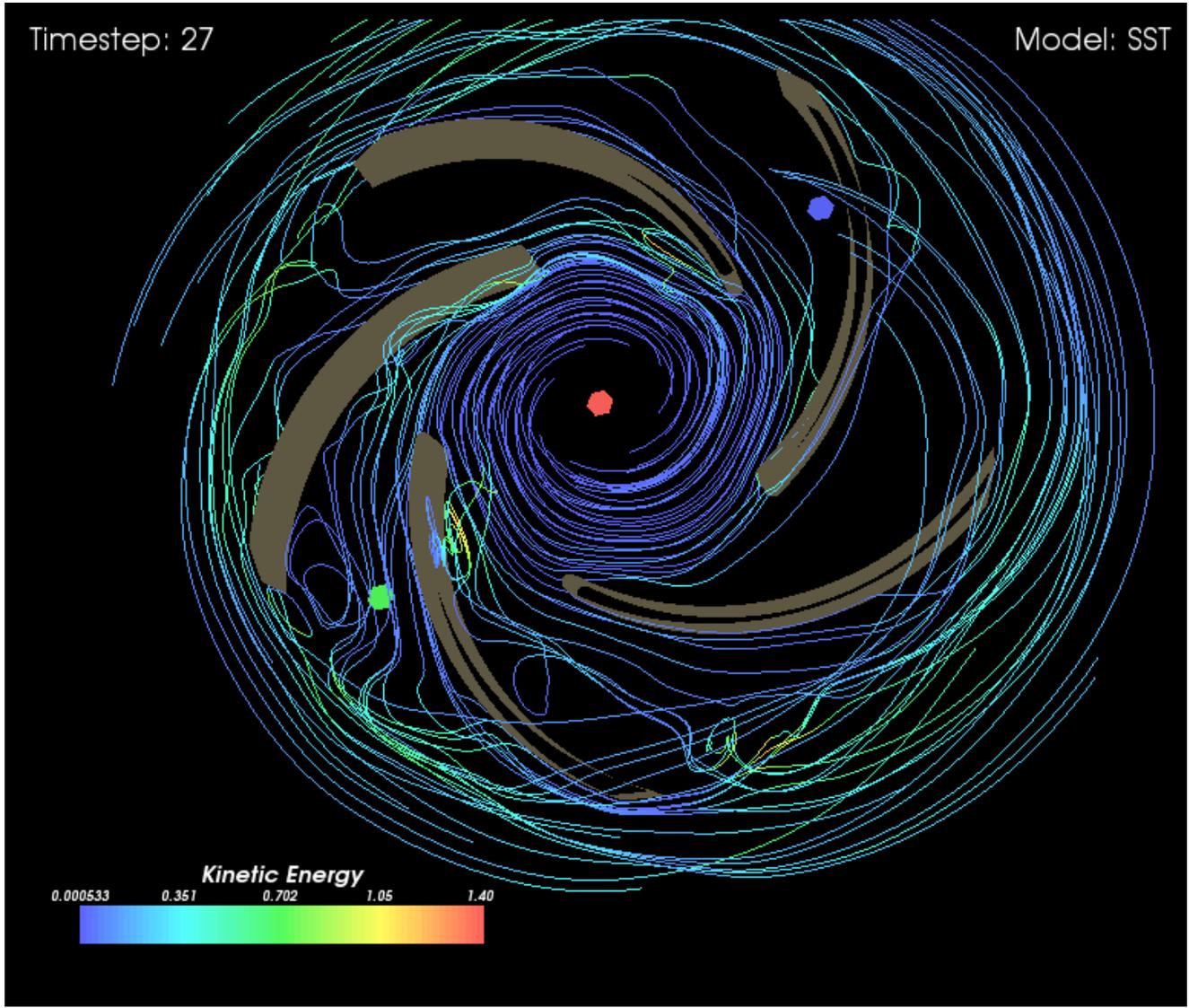


Figure 9. Coloring by Kinetic Energy. Instabilities pop out better. SST model

Timestep: 70

Model: SAS

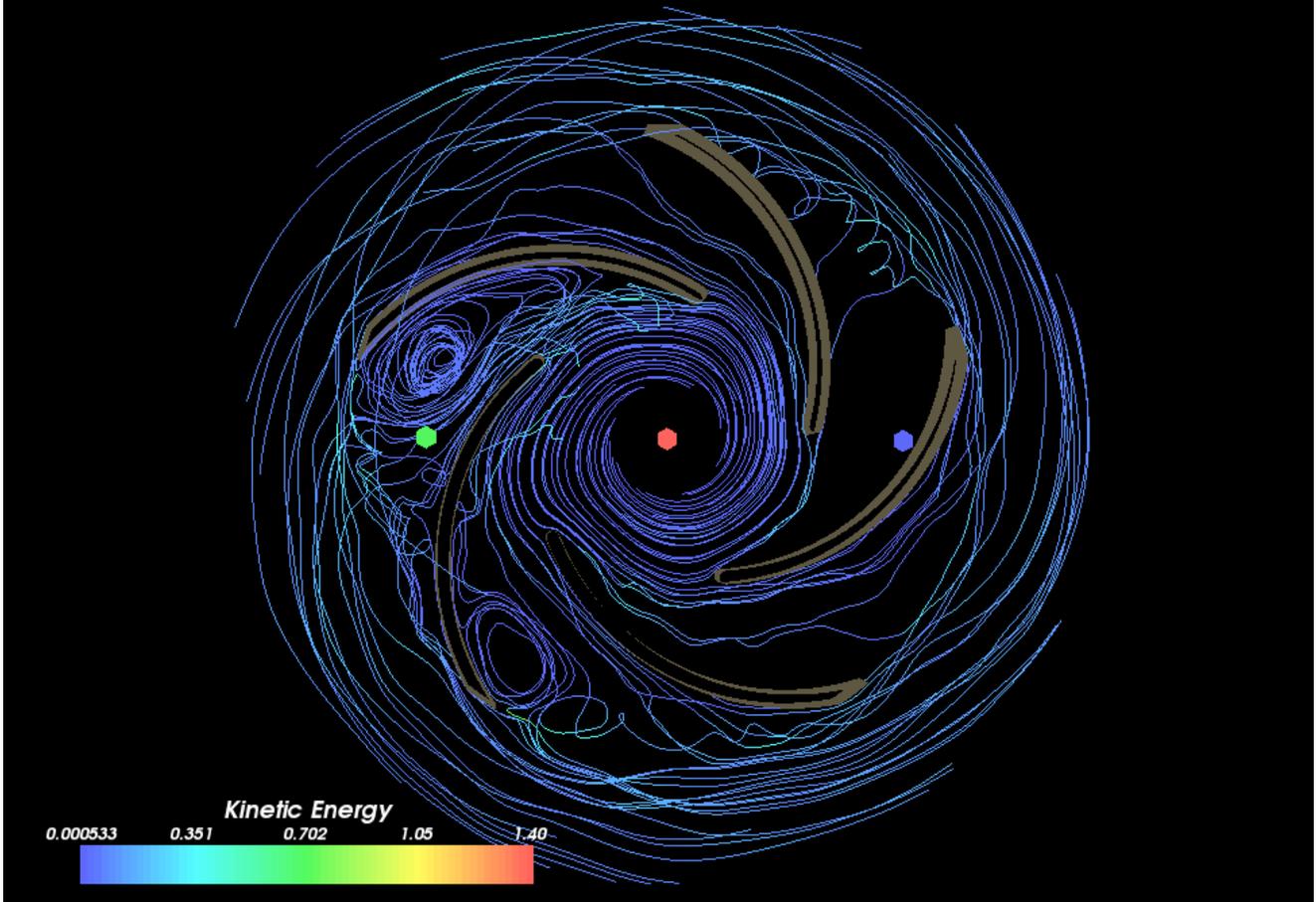


Figure 10. Coloring by Kinetic Energy. SAS model

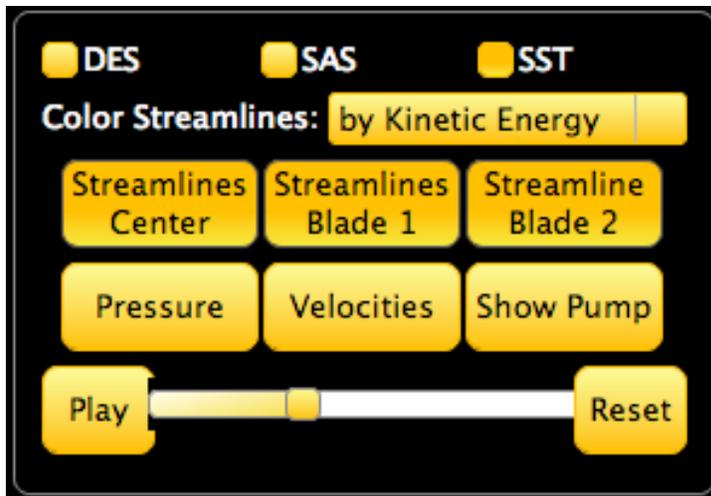


Figure 11. The control Area