The Use of CFD to Analyze and Predict the Pressure Drop Along Flat Oval Duct Fittings

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I. Introduction

When designing a duct system, it is important to take into account the pressure drop along different fittings in order to understand how air flows through the system. The desired air flow is dependent on the shape and length of the different fittings, but these characteristics are limited by the environment. The ASHRAE Duct Fitting Database is a useful resource for determining the appropriate fitting for different scenarios, but it does not yet have information on all duct fittings available [1].

Flat-oval fittings are used when space is limited; however, not much data is available about them. In the ASHRAE Duct Fitting Database, compared to the data available for round and rectangular ducts, only a few flat-oval fittings have data readily available. This is in part because lab experiments are relatively expensive and difficult to set up. In order to populate the database with flat-oval fittings data, this project will use Computer Fluid Dynamics (CFD) to first, validate that CFD can be used in place of lab experiments and second, find the pressure drops along flat-oval fittings that are not yet in the database.

II. Literature Review

Pressure drop along a duct fitting is a product of surface friction and drag due to separation. It varies with velocity, duct size and length, and wall roughness [10]. Additionally, when there is turbulent flow due to sudden changes in direction, like in elbows, the pressure loss becomes greater than in straight ducts of a similar effective length.

For the most part, the pressure drops along duct fittings of different cross sections are found through lab experiments [3-5,11-13]. The results from these experiments were used to populate the ASHRAE Duct Fitting Database. If the dimensions of a duct fitting are inputted into the database, the pressure drop can be calculated by interpolation from existing data. To get accurate results from a lab experiment, it is necessary to have a flow development section before the duct fitting being observed, the length of which varies depending on the fitting. This set up requires a large area and is relatively expensive to setup.

To replace the need for lab experiments, there have been studies into the performance of CFD as a method to find pressure drop and loss coefficients along fittings. Pressure drop and loss coefficient are related by the following equation:

$$\Delta P = CV_P \tag{1}$$

where ΔP is the pressure drop, C is the loss coefficient, and V_P is velocity pressure. Since they are directly related, any conclusions about loss coefficients can be applied to pressure drops.

In general, there is a consensus that CFD can be used, but more research is still needed. A study performed by Mumma et al determined that surface roughness could not be ignored when performing a computer simulation, as assuming smooth walls resulted in notable discrepancies [8]. An investigation performed by Liu et al found that varying the surface roughness of straight ducts varied the predicted pressure loss coefficients as well, indicating there is a relationship between the two [6]. Gutovic et al performed a CFD analysis on flat-oval duct fittings to find loss coefficients and found that, while the CFD results had the same physical trend as the experimental results, they differed quantitatively [2]. However, in another study by Manning et al, it was concluded that CFD could be used to predict the magnitude of loss coefficients [7].

It is important to note that the flow through air ducts is not completely uniform throughout the entire profile of the duct fitting [9]. The flow near the walls of duct fittings are dependent on roughness of the boundaries, while the flow through the center region is independent of them.

III. Objective and Deliverables

The objective of this project is to, first, validate that CFD can be used to find the pressure drop along flat-oval fittings by comparing the simulated results to experimental results found in the ASHRAE Database. In the CFD studies mentioned in the previous section, the results were considered successful if the computed pressure drops or loss coefficients fell within 15% of the experimental data.

After verifying the validity of CFD, the same equations and setup in Fluent will be used to find the pressure drop of flat-oval fittings that are not yet in the ASHRAE database.

IV. Methods

The CFD package used will be Fluent 19.0, in which there are many viscous models available. From the mentioned studies using CFD, the k-ε and RSM models provide the most accurate results for steady-state flow. The LES model, which is also available in Fluent, works best for transient flow, which will not be looked at in the project.

An iterative process will be used to verify the mesh used on each fitting gives accurate results. The average aspect ratio and element qualities of the elements should be as close to 1 as possible, and the average skewness should be as close to zero as possible. After the program is first run, it will be run again with a finer mesh. If the results do not change significantly, the mesh used originally is satisfactory. However, if the results are noticeably different, then the analysis will need to be run again until a good mesh is found.

The only flat oval fittings available on the ASHRAE Duct Database are the straight duct and the 5 gore 90˚ hard bend. Therefore, these fittings will be used to validate the CFD process and find an appropriate model that can be used for other fittings. A model is considered successful if there is less than a 15% error between the computer results and the database.

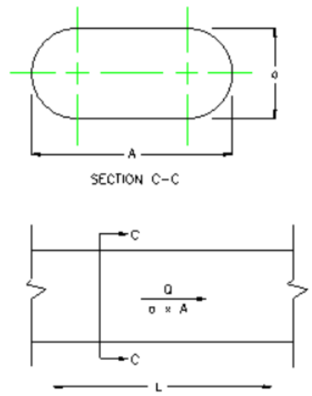

Figure 1: Flat Oval Straight Duct [1]

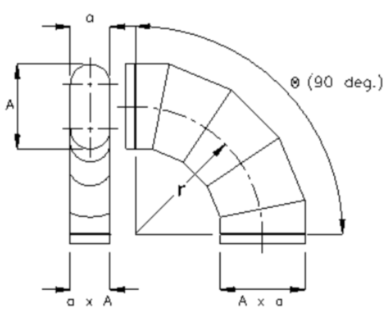

Figure 2: Flat Oval 5 Gore 90˚ Hard Bend [1]

Once a model is found, it will be validated once again using the round 90˚ mitered elbow and the 3 gore 45˚ elbow. These fittings were chosen to determine whether or not the CFD model could be used for fittings with sudden changes in direction and angles that are less than 90˚. If not, the model will be modified until it is successful.

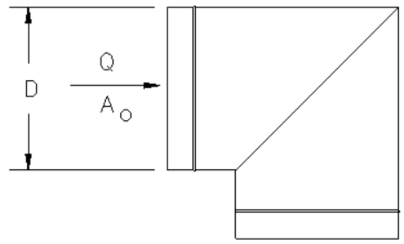

Figure 3: Round 90˚ Mitered Elbow [1]

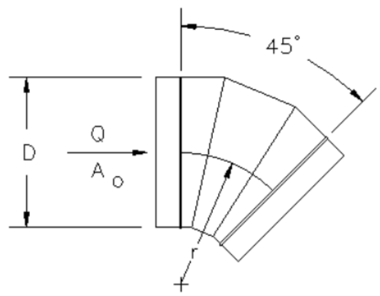

Figure 4: Round 3 Gore 45˚ Elbow [1]

Second, flat oval versions of the round ducts will be looked at. Another reason the round fittings were chosen was because they could potentially be manufactured with flat oval cross sections. If time allows, more theoretical flat oval fittings will be looked at.

V. Timeline

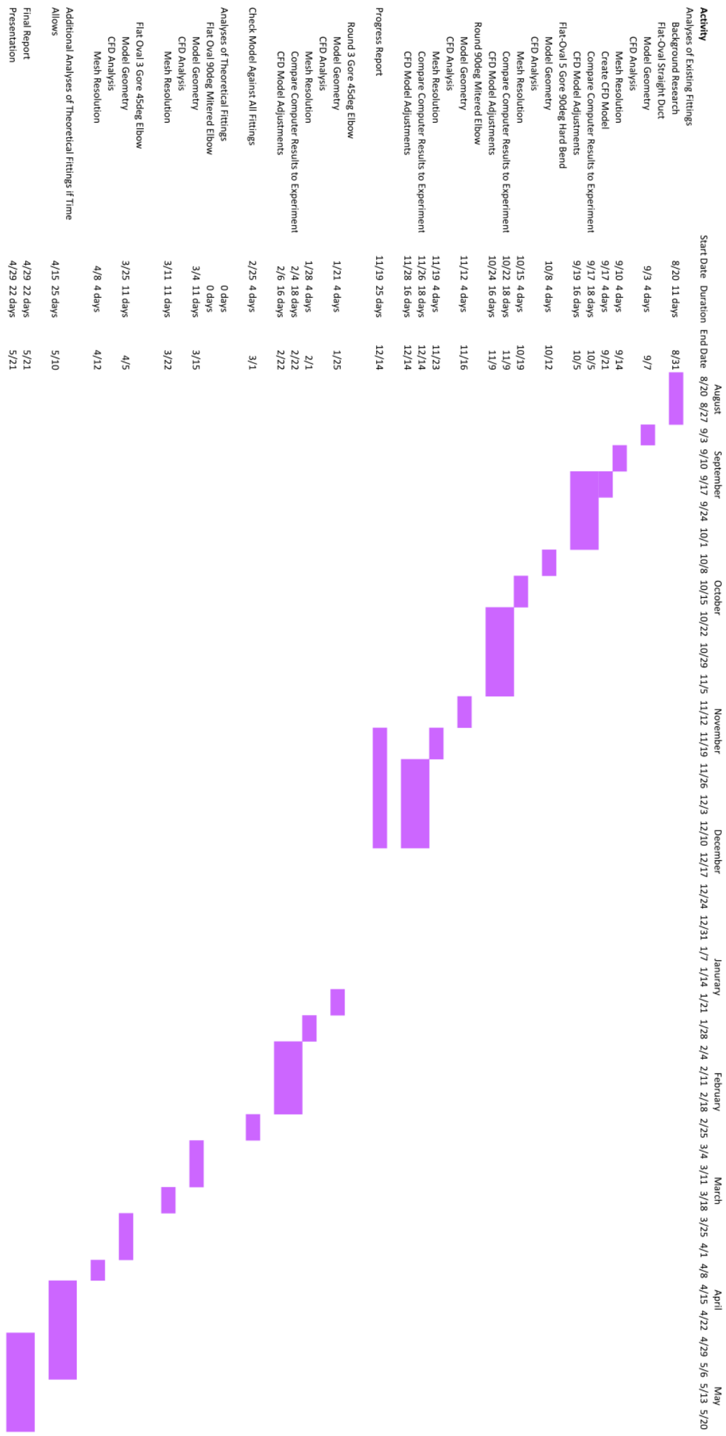

Figure 5: Gantt Chart

VI. References

[1] ASHRAE, 2002, “ASHRAE Duct Fitting Database.” American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Atlanta, GA.

[2] Gutovic, M., Lulic, H. and Dr-Ing, E. S., 2013, “CFD Analysis of Pressure Losses in Flat-Oval Duct Fittings,” *ASHRAE Transactions*, 119(2), pp. 330-340.

[3] Heyt, J. W. and Diaz, M. J., 1975, “Pressure Drop in Flat-Oval Spiral Air Duct.” *ASHRAE Transactions*, 81(2), pp. 221-232.

[4] Kulkarni, D., Cui, J. and Idem, S., 2011, “Laboratory Testing of Converging Flow Flat Oval Tees and Laterals to Determine Loss Coefficients.” *HVAC&R Research*, 17(5), pp. 710-725.

[5] Kulkarni, D., Khaire, S. and Idem, S., 2009, “Measurements of Flat Oval Elbow Loss Coefficients.” *ASHRAE Transactions*, 115(1), pp. 35-47.

[6] Liu, W., Long, Z. and Chen, Q., 2012, “A Procedure for Predicting Pressure Loss Coefficients of Duct Fittings Using Computational Fluid Dynamics.” *HVAC&R Research*, 18(6), pp. 1168-1181.

[7] Manning, A., Wilson, J., Hanlon, N. and Mikjaniec, T., 2013, “Prediction of Duct Fitting Losses Using Computational Fluid Dynamics.” *HVAC&R Research*, 19, pp. 400-411.

[8] Mumma, S. A., Mahank, T. A. and Ke, Y., 1998, “Analytical Determination of Duct Fitting Loss-Coefficients.” *Applied Energy*, 61, pp. 229-247.

[9] Pimental, L. C. G., Cotta, R. M. and Kakac, S., 1999, “Fully Developed Turbulent Flow in Ducts with Symmetric and Asymmetric Rough Walls.” *Chemical Engineering Journal*, 74, pp. 147-153.

[10] SMACNA, *HVAC Systems Duct Design: US & Metric Units - 3rd Edition*, Sheet Metal and Air Conditioning Contractors National Association, Inc., Chantilly, VA.

[11] Smith, J. R. and Jones, J. W., "Pressure Loss in High Velocity Flat Oval Duct Fittings." *ASHRAE Transactions*, 82(1), pp. 244-255

[12] Townsend, B., Khodabakhsh, F. and Idem, S., 1996, "Loss Coefficient Measurements in Divided-Flow Flat Oval Fittings." *ASHRAE Transactions*, 102(2), pp. 151-158.

[13] Townsend, B., Khodabakhsh, F. and Idem, S., 1996 "Loss Coefficient Measurements for Flat Oval Elbows and Transitions." *ASHRAE Transactions*, 102(2), pp. 159-169.