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When I first arrived at Siemens Power Generation, Inc., I was not sure what to expect. This was my first internship that actually pertained to engineering, and I was extremely nervous. I certainly didn't expect this internship (or any internship, to be perfectly honest) to be one of the most educationally-rewarding experiences of my academic career. My previous experience with internships consisted of being assigned mostly "temp work" – data entry and things of that nature; this was also the vibe I got from several of my friends when they talked about their internships. While I wasn't expecting three months of that, I was certainly prepared for a few weeks of it before I got a real project. I couldn't have been more wrong. I'm pretty sure I would have been assigned my project the first day I started work had it not been for several issues IT was having with my computer; these problems actually turned out to be rather serendipitous. The two weeks spent fixing my computer gave me the time I needed to brush-up on heat transfer – the principal heat transfer engineer, Bob Scott, gave me several textbooks to read and also provided me with turbine-specific applications of heat transfer.

After my self-taught heat transfer refresher course, I was ready to start my project. Siemens-Westinghouse has several in-house tools that it uses to analyze heat transfer and fluid flow through a turbine blade or vane. In addition to the three-dimensional modeling and computational fluid dynamics tools, there is another program called K1D. K1D, while simpler to use than any of the other 3D CFD programs, is incredibly powerful. Given just a few inlet and outlet flow conditions and some geometry, K1D is able to iteratively solve for all the flow conditions in between as well as the most important parameter: the heat transfer coefficient (HTC) of each cell.

The heat transfer coefficient is extremely important because it is what determines how effectively the turbine blade or vane is cooled. A large HTC corresponds to a large amount of heat transfer – this condition is what the designers want on the inside of the turbine blade. Since the blade is hot and the air flowing through the inside is cool, a large amount of heat transfer means that the blade will cool down while the air heats up as it passes through the interior. Conversely, on the exterior of the blade, a small value of HTC is desirable. Because the exterior of the blade is immersed in the hot flow from the combustor, a large amount of heat transferred from the flow to the blade would not only decrease the efficiency of the turbine but could also cause irreparable damage to the blade itself.

The first step to using K1D is to draw a flow network using a serious of lines and cross-sections. Each segment of a K1D model is called a cell, and a string of cells is referred to as a channel. The user enters geometric constraints for each cell (length, cross-sectional area, and perimeter) along with starting and ending flow conditions (beginning stagnation pressure and temperature, exit static pressure). Additionally, the user sets each cell to a specific physical feature – a smooth duct or a ribbed pipe, for example. K1D tracks these physical features through the use of correlations: a smooth duct is represented in the computer code as Correlation 20. Each correlation has its own specific set of formulas used for calculating pressure loss and the heat transfer coefficient of that cell.

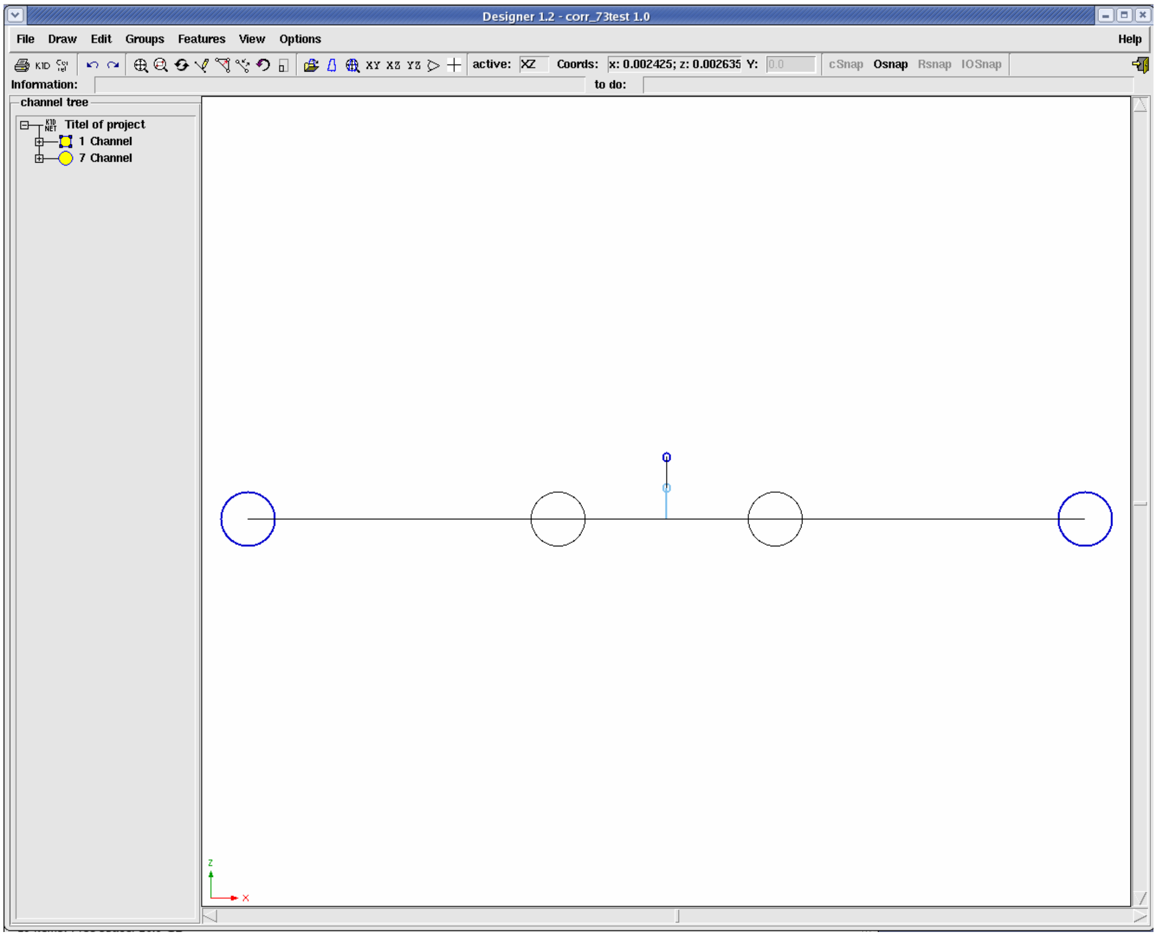
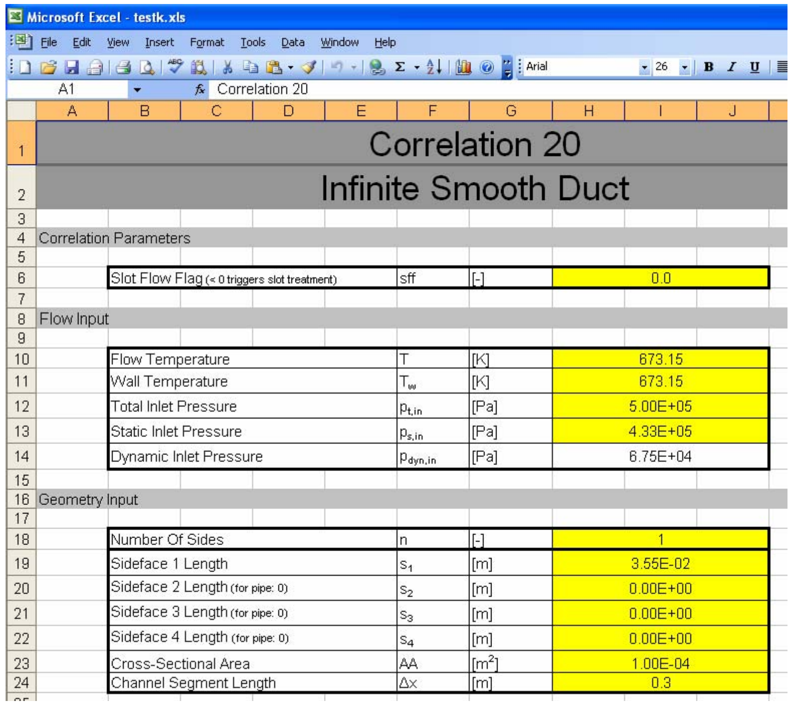


Figure 1: A K1D screenshot showing a simple model of an impingement jet on the interior of a turbine blade.

Each circle in the above picture represents a cross-sectional area – these areas define the start and end of each specific cell. The above model is made up of two channels, the horizontal channel and the vertical channel. The information for each channel is visible in the left vertical menu bar. Each cell in the channel is listed in a drop-down menu under the channel name along with the correlation that it represents.

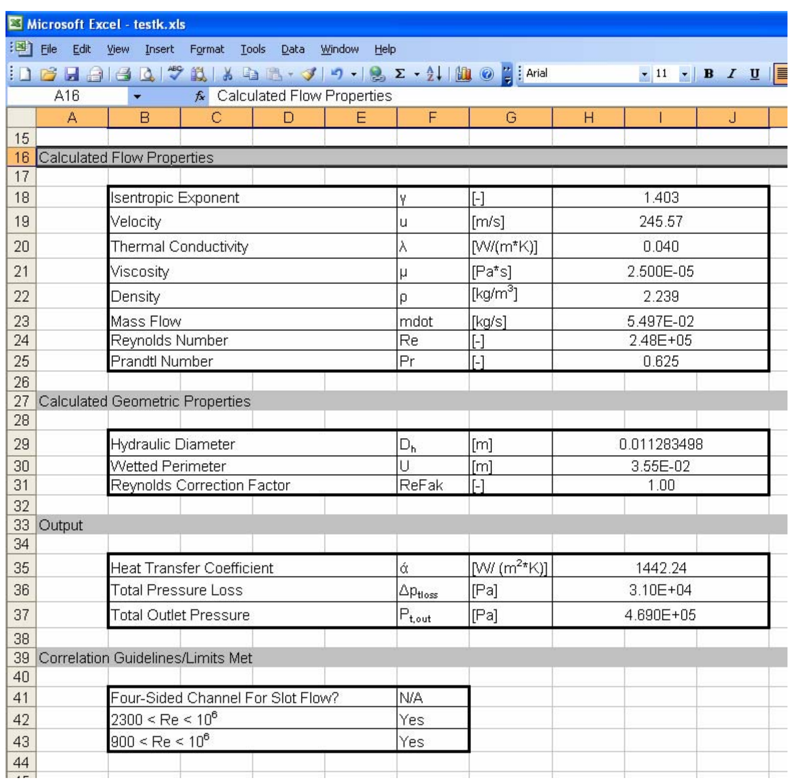
My project was to reprogram each K1D correlation into a Microsoft Excel model for several reasons. First, because K1D is so heavily relied on, it is important to make sure that the results K1D calculates not only make sense but follow the experimentally-derived formulas for different physical arrangements. Additionally, the methods used by K1D are documented in a correlation summary document which is used as a quickreference guide to K1D. Using the correlation document first, I created an Excel model with Visual Basic coding for each correlation. Comparing the results I obtained from Excel to the results obtained from trial runs of K1D led me to notice many discrepancies between the two. By going back to the original FORTRAN source code of K1D, I identified several errors in the K1D correlation summary document. After making the necessary changes to my Excel models, I was able to match the results from K1D in nearly every case. The significance, of course, is that by using the experimentally-derived formulas in my code and obtaining nearly the same results as K1D (in most cases, the average difference was under 2%), it was shown that K1D does in fact accurately make use of the proven formulas.

Secondly, a K1D model can be quite time-consuming to create, especially if the designer is only interested in the way one cell's characteristics change with geometric or fluid property changes. Rather than creating a model; entering the geometric constraints, fluid starting properties and correlation; waiting for K1D to iteratively find the solution; and opening an output file, the user would simply enter the geometric and fluid properties into the appropriate Excel model and the results for that cell would be displayed immediately in the same spreadsheet. While these Excel models are not capable of the same order of complexity as K1D, the designer who wished to see quickly and accurately how one cell's properties changed with different input conditions would be able to make use of these Excel models. In the picture below, the user enters the parameters into the fields highlighted in yellow. While it may seem like as much work as entering them into K1D, I assure you from personal experience it is not. The format of the results from the Excel models can be seen in Figure 3.



	Correlation 20			
	Infinite Smooth Duct			
4	Correlation Parameters			
6	Slot Flow Flag (< 0 triggers slot treatment)	sff	[-]	0.0
8	Flow Input			
10	Flow Temperature	T	[K]	673.15
11	Wall Temperature	T_w	[K]	673.15
12	Total Inlet Pressure	$p_{t,in}$	[Pa]	5.00E+05
13	Static Inlet Pressure	$p_{s,in}$	[Pa]	4.33E+05
14	Dynamic Inlet Pressure	$p_{dyn,in}$	[Pa]	6.75E+04
16	Geometry Input			
18	Number Of Sides	n	[-]	1
19	Sideface 1 Length	s_1	[m]	3.55E-02
20	Sideface 2 Length (for pipe: 0)	s_2	[m]	0.00E+00
21	Sideface 3 Length (for pipe: 0)	s_3	[m]	0.00E+00
22	Sideface 4 Length (for pipe: 0)	s_4	[m]	0.00E+00
23	Cross-Sectional Area	AA	[m^2]	1.00E-04
24	Channel Segment Length	Δx	[m]	0.3

Figure 2: Parameter input section of a typical K1D correlation-Excel model.



16	Calculated Flow Properties			
18	Isentropic Exponent	γ	[-]	1.403
19	Velocity	u	[m/s]	245.57
20	Thermal Conductivity	λ	[W/(m*K)]	0.040
21	Viscosity	μ	[Pa*s]	2.500E-05
22	Density	ρ	[kg/m^3]	2.239
23	Mass Flow	mdot	[kg/s]	5.497E-02
24	Reynolds Number	Re	[-]	2.48E+05
25	Prandtl Number	Pr	[-]	0.625
27	Calculated Geometric Properties			
29	Hydraulic Diameter	D_h	[m]	0.011283498
30	Wetted Perimeter	U	[m]	3.55E-02
31	Reynolds Correction Factor	ReFak	[-]	1.00
33	Output			
35	Heat Transfer Coefficient	α	[W/ (m^2*K)]	1442.24
36	Total Pressure Loss	Δp_{tloss}	[Pa]	3.10E+04
37	Total Outlet Pressure	$P_{t,out}$	[Pa]	4.690E+05
39	Correlation Guidelines/Limits Met			
41	Four-Sided Channel For Slot Flow?	N/A		
42	$2300 < Re < 10^6$	Yes		
43	$900 < Re < 10^6$	Yes		

Figure 3: Calculated results section of a typical K1D correlation-Excel model.

I mentioned earlier that this internship has been invaluable to my educational career. Not only was I able to apply the knowledge and critical-thinking skills I've learned in my undergraduate career, but I learned a great deal about what makes a successful work environment. One of the areas I made the greatest improvement by far was communication. My weekly meetings to discuss my project provided me with the opportunity to discuss my results and choices I had made clearly and concisely. I am not sure that I always came across as such, but I could tell that my skills were improving as the weeks passed. I realized the importance of scheduling specific goals for myself to make sure that I not only moved forward as quickly as possible, but to ensure that I did as good a job as I was capable of doing.

I'd like to conclude by expressing my sincere thanks to everyone at Siemens who made my internship both educational and enjoyable. The lessons I've learned here will help me through my last semester of school and beyond into whatever I pursue after that. I'd also like to thank everyone at UTSR for giving me this incredible opportunity. I can honestly say that this experience has been one of the best semesters I've ever had.