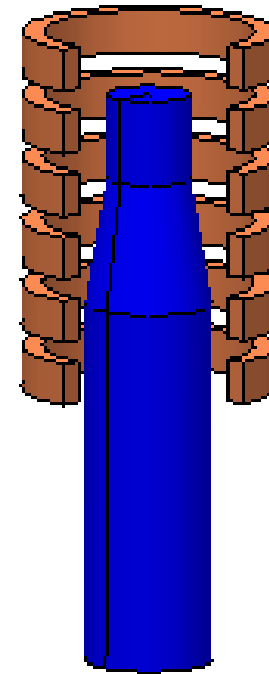


# Coil Size Optimization - Induction Heating

# Coil Size Optimization - Induction Heating

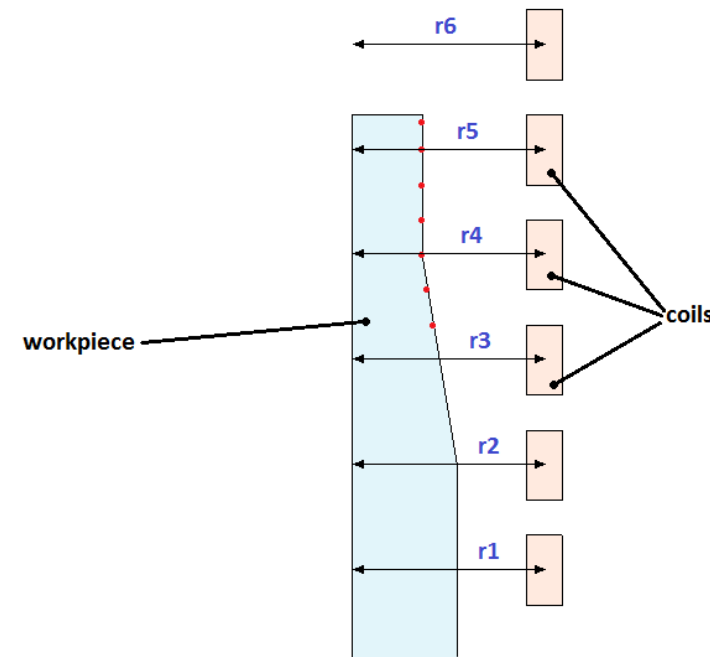
In the multiple-coil configuration shown in this figure, the work piece is surrounded by six coils (coils are shown partially so that the workpiece can be seen). The objective of this optimization is to find the inner radii of the coils in order to obtain a uniform temperature in the upper portion of the workpiece.

The coupled electromagnetic-thermal simulation is a transient thermal solution that, at each time step during the transient process, performs a time-harmonic electromagnetic solution to update the eddy current losses. The workpiece is made of stainless steel and its material properties are non-linear and vary with temperature.

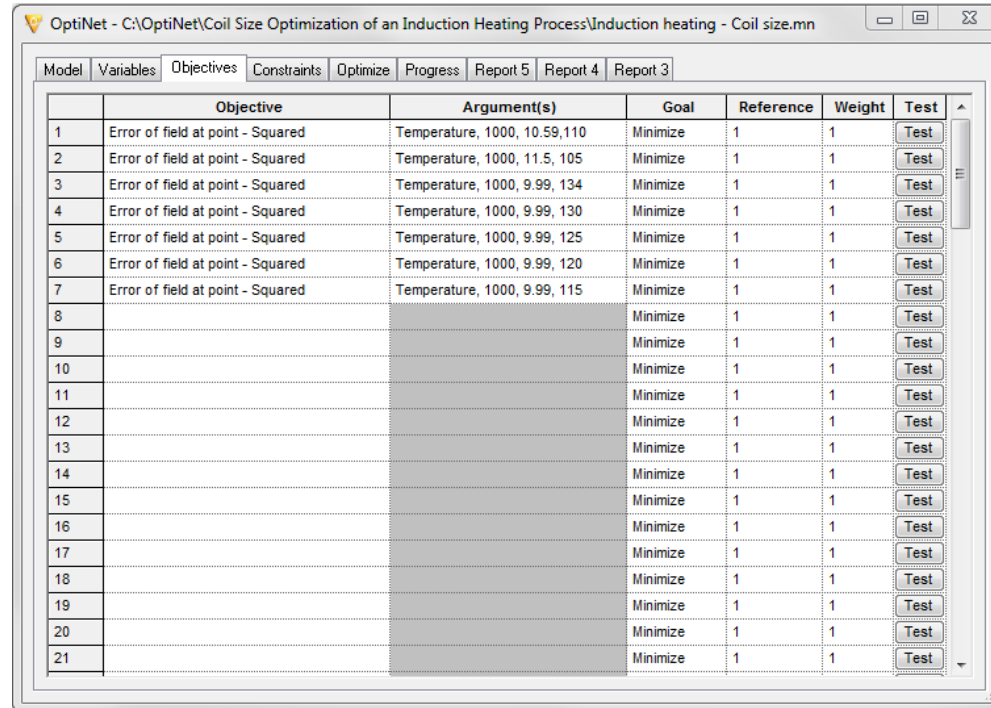


# IDENTIFYING THE PARAMETERS

The geometry of the six coils is defined based on the parameters  $r1$  to  $r6$ .  $r1$  is the inner radius of the bottom coil,  $r2$  is the inner radius of the next coil, etc. The points where the temperature is measured are shown in red. In OptiNet, a minimum and a maximum value for each variable is specified. OptiNet then searches within this range to find the optimum design



# OBJECTIVE FUNCTION - MINIMIZING THE RMS ERROR

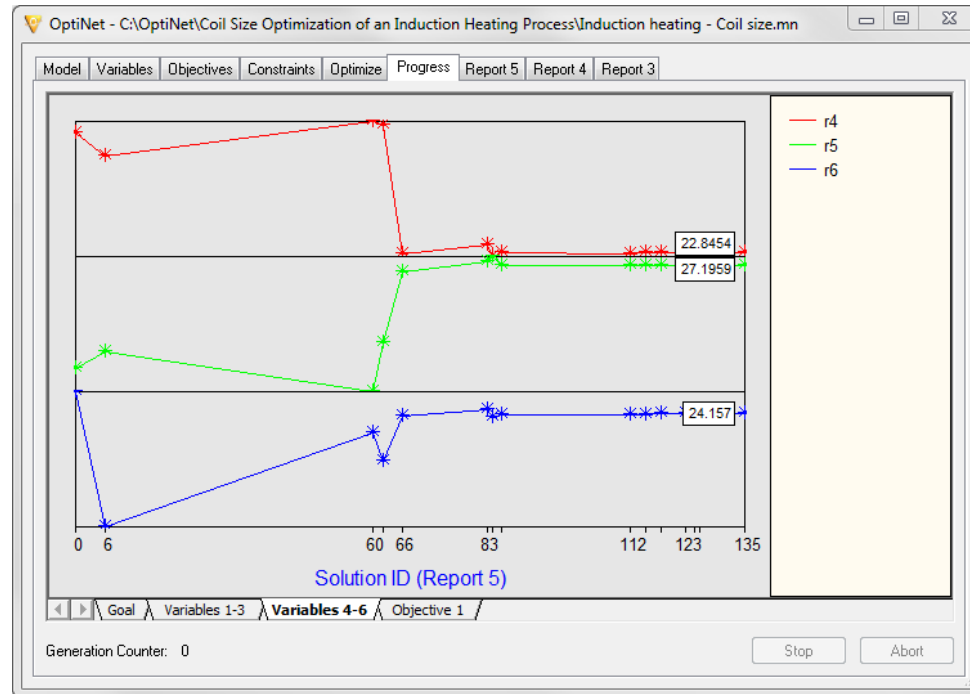


The screenshot shows the OptiNet software interface with a table of objective functions. The table has columns for Objective, Argument(s), Goal, Reference, Weight, and Test. The first seven rows show objectives for minimizing the squared error of temperature at various points, with arguments including 'Temperature, 1000' and specific time and point values. The remaining rows (8-21) are currently empty or greyed out.

	Objective	Argument(s)	Goal	Reference	Weight	Test
1	Error of field at point - Squared	Temperature, 1000, 10.59, 110	Minimize	1	1	Test
2	Error of field at point - Squared	Temperature, 1000, 11.5, 105	Minimize	1	1	Test
3	Error of field at point - Squared	Temperature, 1000, 9.99, 134	Minimize	1	1	Test
4	Error of field at point - Squared	Temperature, 1000, 9.99, 130	Minimize	1	1	Test
5	Error of field at point - Squared	Temperature, 1000, 9.99, 125	Minimize	1	1	Test
6	Error of field at point - Squared	Temperature, 1000, 9.99, 120	Minimize	1	1	Test
7	Error of field at point - Squared	Temperature, 1000, 9.99, 115	Minimize	1	1	Test
8			Minimize	1	1	Test
9			Minimize	1	1	Test
10			Minimize	1	1	Test
11			Minimize	1	1	Test
12			Minimize	1	1	Test
13			Minimize	1	1	Test
14			Minimize	1	1	Test
15			Minimize	1	1	Test
16			Minimize	1	1	Test
17			Minimize	1	1	Test
18			Minimize	1	1	Test
19			Minimize	1	1	Test
20			Minimize	1	1	Test
21			Minimize	1	1	Test

The objective is to obtain a temperature of 1000 degrees Celsius after 25 seconds at the surface in the upper section of the workpiece. The objective function is specified as the RMS error representing the deviation of the temperature values at several points from 1000 degrees. The goal is to minimize this RMS error. In OptiNet, it is possible to use any quantity obtained from ThermNet and use it as an objective. In this case, the temperature value at a particular point and time in the transient thermal solution is selected.

# PROGRESS PAGE - (GOAL, VARIABLES, OBJECTIVES, AND CONSTRAINTS)



For every iteration of the optimization process, OptiNet updates and displays the changes (in the form of graphs) for the goal, variables, objectives, and constraints -- these graphs are displayed on the Progress page. In this example, each of the six variables' graphs is updated as OptiNet finds a new design.

# REPORT GENERATOR - VIEW INDIVIDUAL DESIGNS

OptiNet produces a report for each optimization run. In this report, the designs that satisfy the constraints are shown in the order that they are improved. The user can view each design individually. The report also shows the time that it took to arrive at the improved design. The values of all the variables and the optimization function are displayed in this report for every iteration. The values of each parameter can be examined to determine the sensitivity of the design to that particular parameter.

The screenshot shows the OptiNet software interface with a report window open. The report displays a table of optimization results for 'Report 5'. The table has columns for Solution ID, Time (s), Goal, and four variables (r1, r2, r3, r4). The data is sorted by time, showing the progression of designs from 67 to 139. Design 139 indicates 'Convergence Reached'. Below the table, there is a status bar with optimization details and control buttons.

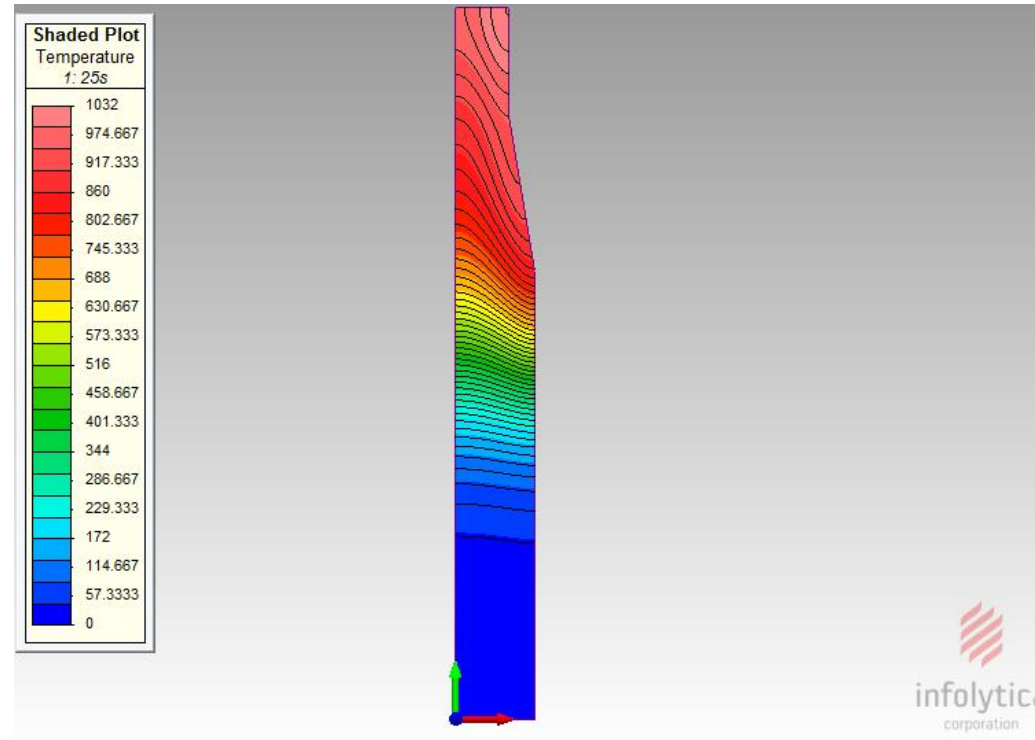
	Solution ID	Time (s)	Goal	r1	r2	r3	r4
67	66	8365	10.3698253535076	22.2169047875895	33.9571049624657	19.6967778994263	22.835382435
84	83	10498	9.3177316778947	21.8415406555317	33.464817995539	19.5497666935636	22.999033672
85	84	10622	7.96421459559417	21.8925941514789	33.2707554472195	19.3719582719365	22.784196223
87	86	10876	7.05346526304686	21.9957490547652	32.8731567852664	19.4611792572678	22.852108324
113	112	14163	6.85141034020842	22.0109063413568	32.8830864604949	19.4737951675214	22.841376089
116	115	14540	6.75192185098638	21.9921688250838	32.870359653038	19.4725181492906	22.848643051
119	118	14923	6.7280643951043	21.9984626188348	32.8808068497653	19.4653000478404	22.845279047
124	123	15567	6.72346555243632	21.9922972627929	32.8723318135489	19.4668923640747	22.842627543
126	125	15820	6.64717283979508	21.9956899410802	32.8720990833229	19.4716175701587	22.844641401
127	126	15946	6.62591626841856	21.9960471824587	32.8740676446339	19.4735294676811	22.845279347
136	135	17082	6.59916250969479	21.9948928374508	32.8779530983779	19.4751310573459	22.845403432
139	Convergence Reached						

Optimization report 5 started on: 25/08/2011 5:23:24 PM (computer: LHDTSE, user: rifat)  
Model: C:\OptiNet\Coil Size Optimization of an Induction Heating Process\Induction heating - Coil size.mn  
Program: ThermNet 7.2.0  
Solver: Transient 2D + Magnetic Time-Harmonic 2D

Show only improved solutions      Seed used: 42098.140625

View Model    Animate Models    Reuse    Delete    Graph

# INITIAL DESIGN - TEMPERATURE VARIATION



In the initial design that the user supplied to OptiNet, the temperature variation was obtained and is shown in this figure.

# FINAL DESIGN - SIGNIFICANT REDUCTION IN TEMPERATURE VARIATION

The final design that OptiNet produced is shown in this figure. As can be seen, the variation in temperature in the upper section of the workpiece has been reduced significantly. Of course, the user can examine previous improved designs. In this case, the variation in temperature had dropped significantly during the 80 first steps of the optimization process (see graph of goal) and during the remaining time OptiNet tried to find further improvement.

In OptiNet, it is possible to stop the solution at different points, to examine the design and re-start the optimization process, for further improvements.

