CFD Assists Neonatal

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Pathlines, colored by temperature, illustrated the circulation inside the left side of the incubator
Postprocessing courtesy of Michał Nowak

PREMATURE INFANTS generally enter the world with little protection from the harsh environment. Thermal comfort thus plays a crucial role in their survival and health. To provide the optimal environmental conditions for these infants, incubators are widely used. However, due to the complexity of the physical processes occurring within modern neonatal units during treatment procedures, comprehensive analysis involving the thermal comfort of premature infants can be difficult. The application of analytical calculations is currently not practical, and therefore numerical modeling is required.

At the Silesian University of Technology in Gliwice, Poland, a CFD model of conjugate fluid flow and heat transfer in an infant incubator has been developed to support infant healthcare and improve medical equipment design. Accurate geometrical models representing the human body in a variety of postures are now easily created with high accuracy. Fluid flow analysis can be performed by taking into account mechanisms of heat transfer, such as radiation, convection, conduction, and even the evaporation of sweat and moisture from human skin.

Since all infants, and particularly premature infants, are different from each other, the complex shape of the human body was generated using the CATIA package and described by a number of scaleable parameters. By changing the value of those parameters, a geometrical model can easily be adjusted to the individual

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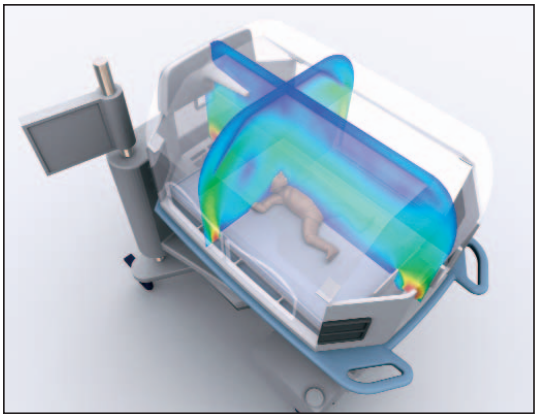
features of each analyzed patient or to his nursing position. The researchers used TGrid 4.0 to wrap the surface model of the infant's body and to create the surface mesh to be exported to GAMBIT. In parallel, they created the geometry of the incubator using the CATIA package and combined the baby and incubator geometries using GAMBIT.

Once a fine tetrahedral volume mesh was created, numerical calculations were performed in FLUENT. The research team enhanced the FLUENT model using several user-defined functions (UDFs) to control the processes of heat transfer together with internal heat generation inside the infant's body, evaporation of moisture from the infant's skin, and respiration. This last component of heat balance can be modeled as a steady-state or transient process. To make the calculation process fully automatic, managing software called MARCEL was developed to assist the team at all essential stages of the numerical simulation. MARCEL reads the provided data, manages the process of geometry and mesh creation, and sets the appropriate boundary and initial conditions. After receiving the results from the CFD solver, MARCEL then provides a basic report about the heat balance of the infant being analyzed. It is anticipated that a modified version of the program could be used by medical staff to perform heat balance calculations without possessing any knowledge of how to build and run CFD models.

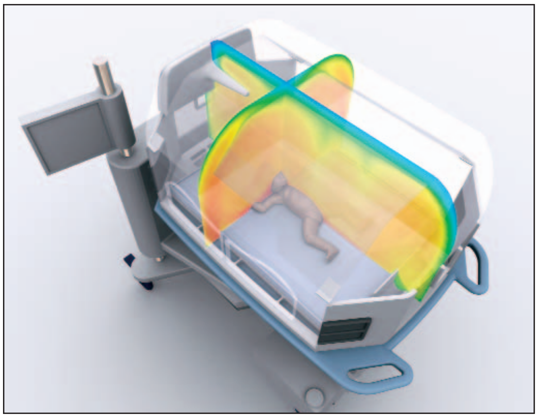
Validation of the code has been performed with comparison of the results to a series of clinical tests described in the medical literature. In all cases numerical models were created to represent analyzed infants and environmental conditions measured in the described tests. Results from the numerical simulations were compared with those obtained from the literature and proved to be very accurate.

Researchers also performed a series of air temperature and velocity measurements inside an empty prototype of a new design. These measurements were fairly consistent with the results obtained from the numerical simulations. Based on this conclusion, modification of the ventilation system has been proposed and verified numerically.

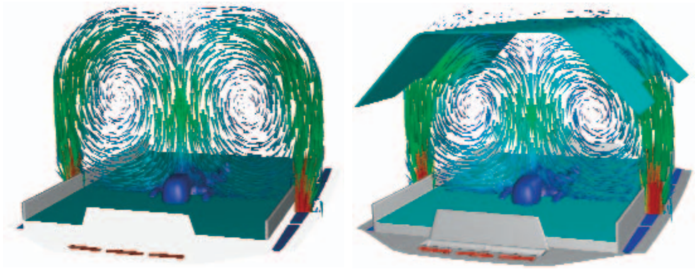
The incubator modeling project is still in the phase of testing and validation. However, even at the present stage, it is providing crucial information and is becoming an important tool in the treatment of premature babies at neonatal intensive care units. ■



Contours of velocity magnitude on two planes through the incubator; red regions correspond to the flow inlets at the ends and outlets at the sides



Temperature contours show a uniform field in the region surrounding the infant



Velocity vectors without (left) and with (right) an overhead plastic screen; the screen was found to help reduce radiative heat loss from the child

Suggested Reading:

Ginalski, M., Nowak, A.J. and Wrobel, L.C.: Computational Model of Selected Transport Processes of the Premature Newborn Baby within an Infant Incubator. XXI International Congress of Theoretical and Applied Mechanics, Conference proceedings, Warsaw, Poland, August 2004.

Ginalski, M., Nowak, A.J. and Wrobel, L.C.: Combined Heat and Fluid Flow in a Double Wall Infant Incubator. International Conference of Computational Methods in Sciences and Engineering, Conference proceedings, Loutraki, Greece, October 2005.

Ginalski, M., Nowak, A.J. and Brandt, J.: Numerical Optimization of the Infant Incubator Ventilating System. Conference Proceedings, XIX National Congress of Thermodynamics, Sopot, Poland, September 2005.

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