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3D Heat Transfer of an Injection Mold: ANSYS Workbench and Mechanical APDL [†]

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Abstract: Recent advancements in additive manufacturing have facilitated the production of conformal cooling channels with greater ease and cost-effectiveness. Compared to typical channels that are straight-drilled, conformal cooling channels (CCC) provide enhanced cooling efficacy in the context of the injection molding process. The main rationale behind this is because CCC possess the ability to conform to the shape of a molded object, which is not possible with conventional channels. CCC save the potential to mitigate thermal stresses and warpage, decrease cycle times, and achieve a more homogeneous temperature distribution. Traditional channels utilize a design technique that is more intricate in comparison to CCC. The utilization of computer-aided engineering (CAE) simulations is crucial in the development of a design that is both efficient and cost-effective. The primary objective of this paper is to assess the efficacy of two ANSYS modules to validate the obtained results. The two modules demonstrate similar outcomes when used to models with a fine mesh. Hence, it is crucial to consider the purpose of the study and the intricacy of the computer-aided design (CAD) geometry to make an informed choice regarding the appropriate ANSYS module to utilize.

Keywords: conformal cooling; injection molding; computer aided engineering

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1. Introduction

The affordability and simplicity of conformal cooling channels (CCCs) have been enhanced due to the utilization of additive fabrication techniques. The cold injection molding technique employed by CCC exhibits exceptional characteristics. CCCs enable the possibility of mitigating both warpage and thermal strains. The evaluation of "part cooling time" was conducted for ABM Saifullah and SH Masood using the ANSYS thermal analysis modules [2]. The researchers conducted an evaluation of individual components and made a comparison between standard and quadratic CCC profiles utilizing Message Passing Interface (MPI) simulation modules. According to the source [3], it was observed that conformal channels exhibited a cooling rate that was 38% faster compared to non-conformal channels. The researchers Gloinn et al. [4] employed ABS polymer as the molten substance and used cooling water to determine the temperature of the mold. The thermal influence of injection molding cooling channel design was explored by Moldflow Plastic Insight 3.1 in 2007. Wang et al. demonstrated the benefits of cooling circuits. A method for design optimization in three-dimensional analysis [5]. A similar study to the present one, but in 2D analysis, was already published [6]. This study presents a comparison between ANSYS Mechanical APDL and ANSYS Steady state/Transient Thermal in Workbench, in 3D transient thermal analysis. This research investigates the process of cross-validating both modules and comprised the determination appropriate meshing settings.

2. Methods

2.1. CAD Models (Computer Aided-Design)

The CAD model for this project was built in the commercial *software* ANSYS Workbench and ANSYS Mechanical APDL 2020 R2. The three-dimensional (3D) geometry comprises of eight circular cooling channels, a rectangular mold cavity and enclosure, and a curved plate representing the final/manufactured part. The assembly is illustrated in fig. 1.

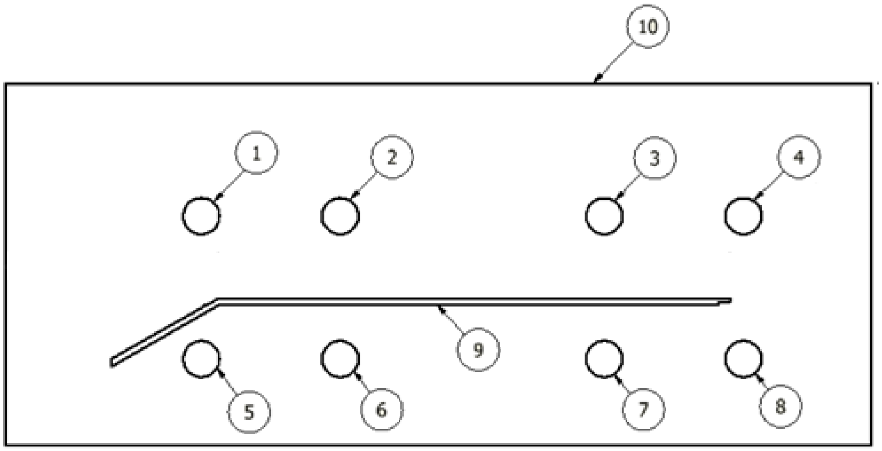

Fig. 1. Assembly drawing of the mold, showing dimensions, in millimeter and components ID.

Table 1 provides an elucidation of the constituent elements of geometry.

Table 1. Components of the geometry used in the simulations and in the optimizations [5,6].

Components	Description
1–8	Cooling Chanels
9	Injected part
10	Mold

2.2. Materials

In the simulations, water was employed in the cooling channels, whereas polypropylene (PP) was used in the injection part. P20 steel was employed for the fabrication of the mold. Among the components, it is considered that only water is a fluid, while both PP and P20 steel are considered to be solid materials. Table 2 presents an overview of the properties of the material.

Table 2. Properties of the materials used in this work [5,6].

Material	Water	PP with 10% Mineral	P20 Steel
Density [(kg/m^3)]	998.2	1050	7861
Specific heat [J/(kg.K)]	4182	1800, Considered constant	502.48
Thermal conductivity [W/(mK)]	0.6	0.2 Considered constant	41.5

2.3. Numerical Procedure

The mesh employed in this study is a quadrilateral free mesh. Despite the fact that both modules used identical mesh parameters, there are notable differences in the meshes generated by Workbench and Mechanical APDL. The reason for this disparity may be attributed to the fact that Workbench's meshing capabilities offer a far wider range of options compared to those of Mechanical APDL. The default values are retained for all Workbench parameters that are not available in Mechanical APDL.t The mesh seen in fig. 2 (left and right) was generated utilizing Mechanical APDL and Workbench *software*.

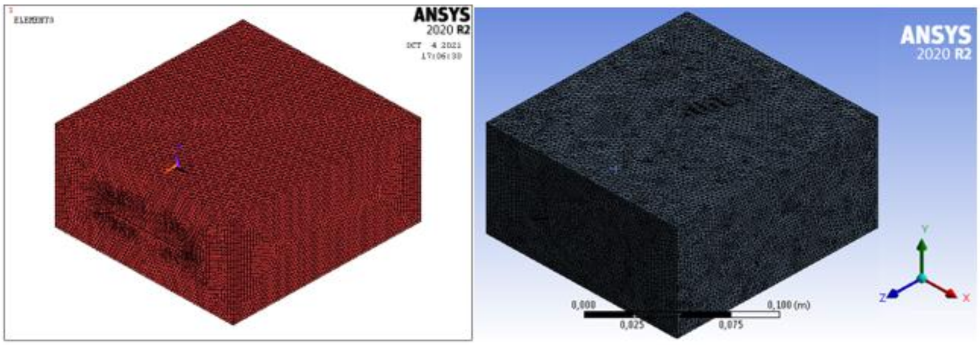

Fig. 2. Mesh in ANSYS Mechanical APDL (**left**) and in ANSYS Workbench (**right**).

The meshing parameters are shown in table 3.

Table 3. Meshing parameters.

Compoments	Esize [mm]	Mesh Type
Cooling channels and mold	2.5	Quadrilateral free mesh
Injected part	0.07	

The injected component is subjected to an initial temperature of 210 degrees celsius. The water temperature within the cooling conduits remains constant at 40 degrees celsius. It is assumed that the ambient temperature is 23 degrees celsius.

3. Results and Discussion

Fig. 3 shows the maximum temperature Tmax in function of time, for both Mechanical APDL and Workbench.

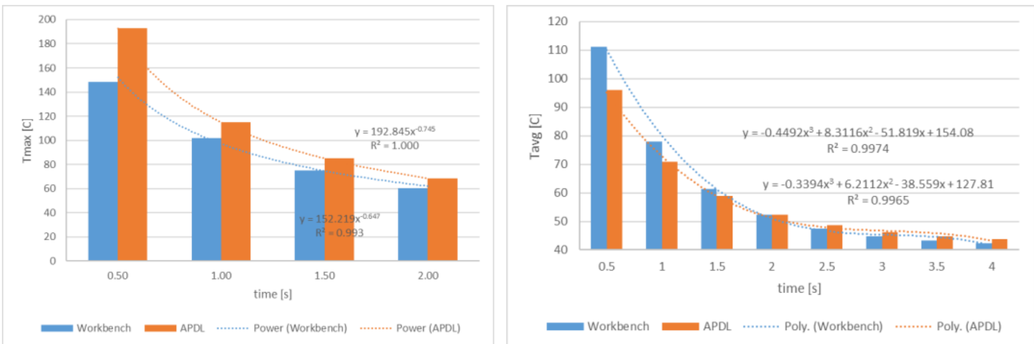

Fig. 3. Maximum temperature (**left**) and average temperature (**right**) in function of time, for both Mechanical APDL and Workbench.

The findings of Workbench are quite close to those of Mechanical APDL, as shown in fig. 3. However, in most cases, Workbench shows maximum temperature readings that are somewhat higher than those of APDL. The average temperature Tavg as a function of time is shown in fig. 4 (left) for both Mechanical APDL and Workbench. Fig. 4 (right) shows the errors in the results, considering the two software. The errors were calculated using (1), considering the results of fig. 3 right (average temperature).

$$|Error|_{[\%]} = \frac{|T_{wb} - T_{APDL}|}{T_{wb}} * 100\% \quad (1)$$

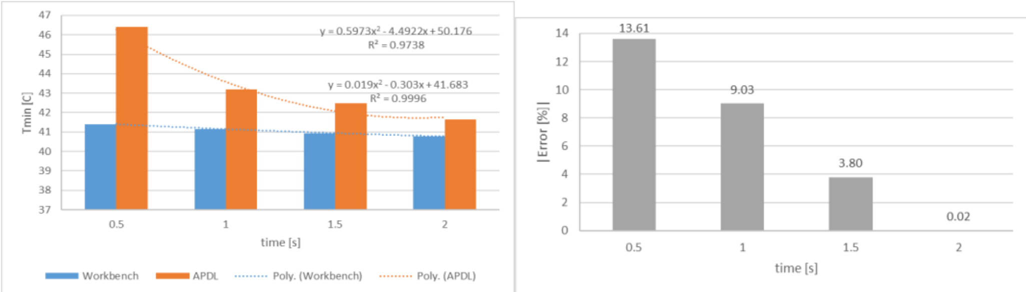

Fig. 4. Minimum temperature in function of time, for both Mechanical APDL and Workbench (**left**) and Error between Mechanical APDL and Workbench, in function of time, for average temperature (**right**).

In fig. 4 (left), it can be observed that Mechanical APDL presents higher values than Workbench. However, the discrepancies between the two software components diminish with time. As seen in figs. 3 and 4, the temperature distribution differs between the two software modules for all of the studied substeps. However, the temperature measurements in ANSYS Mechanical APDL and ANSYS Workbench are somewhat close. As shown in fig. 3 (right), the error as a function of time corresponds to an exponential function for the average temperature Tavg and to a 3rd degree polynomial function for the highest temperature Tmax (fig. 3 left). As seen in fig. 4 (left), the quadratic correlation regarding Tmin is quite close to one.

4. Conclusions

In the present scenario, it may be considered that a mesh with a diameter of 0.07 mm for the injected/final part is sufficiently refined to achieve the necessary level of precision. Despite diligent attempts, significant disparities exist in the module configurations of the two software, hence impeding the feasibility of replicating simulation conditions with absolute precision, particularly regarding meshing characteristics. The mesh parameters and element type were identified as the most notable differentiating factors. As a result, it is possible to observe a significant discrepancy between the two modules when using coarse meshes. However, when considering the finest mesh used, a high level of agreement between the two software is observed. The discovered numerical inconsistencies can be mostly attributed to the differences in the meshing modules of the two software programs, namely in relation to the elements and the overall mesh structure. In future work, there is the potential to predict the differences between the two software systems by means of analytical models/ equations. By using these equations, it could also be possible to ascertain the necessity for additional mesh refinement.

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