JOURNAL OF METALOGRAM
https://www.journal.unrika.ac.id/index.php/metalogram

METALOGRAM
-Mechanical Engineering and Energy-
April 2026. Vol.02 No.02

April, 2026

Thermal Optimization of Aluminium Fishing Sinker Mold Using Cooling Channel Design

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Paper History

Received: January 12th 2026
Received in revised form: February 02nd 2026
Accepted: April 21th 2026

ABSTRACT

Thermal performance of mold plays a critical role in determining the quality and productivity of aluminium casting products, including fishing sinkers. Improper temperature distribution within the mold can lead to casting defects, uneven solidification, and extended cooling time. This study focuses on the thermal optimization of an aluminium fishing sinker mold through the design and improvement of cooling channel configurations. Numerical simulations based on heat transfer analysis are conducted to evaluate temperature distribution, cooling efficiency, and solidification behavior within the mold. Several cooling channel designs are analyzed and compared to identify the most effective configuration for achieving uniform temperature distribution and enhanced heat dissipation. The results show that optimized cooling channel design significantly reduces temperature gradients, shortens cooling time, and improves overall casting quality. This study demonstrates that thermal optimization through proper cooling channel design is an effective approach to enhancing the performance and reliability of aluminium fishing sinker molds.

KEY WORDS: *Thermal optimization, aluminium casting, fishing sinker mold, cooling channel design, heat transfer*.

1. INTRODUCTION

Aluminium casting is widely used in manufacturing industries due to its lightweight properties, good thermal conductivity, and high corrosion resistance. One of the aluminium casting products commonly produced through simple mold systems is the fishing sinker. Although the geometry of a fishing sinker is relatively simple, the quality of the final product is strongly influenced by the thermal performance of the mold during the solidification process. Inadequate temperature control and non-uniform cooling may lead to defects such as shrinkage, porosity, and uneven surface quality.

The cooling system within a mold plays a crucial role in regulating heat transfer during the casting process. Cooling channels are designed to extract heat from the molten aluminium efficiently and to ensure a uniform temperature distribution throughout the mold. Poorly designed cooling channel configurations can result in excessive temperature gradients, prolonged cooling time, and reduced productivity. Therefore, optimizing the cooling channel design is essential to improve both the thermal performance of the mold and the overall quality of the aluminium casting product.

1.1 Background Of The Study

Aluminium fishing sinkers are commonly produced using simple casting molds due to their cost-effectiveness and ease of manufacturing. Despite their simple geometry, improper thermal management during the casting process can significantly affect product quality. Uneven cooling may cause defects such as incomplete filling, surface irregularities, and internal porosity. These issues highlight the importance of effective mold cooling strategies to ensure uniform solidification and consistent product quality.

1.2 Problem Statement

In the aluminium casting process of fishing sinker molds, improper cooling channel design often results in non-uniform temperature distribution within the mold. This condition can cause various casting defects such as porosity, uneven solidification, and surface imperfections. In addition, inefficient heat removal may lead to longer cooling times, which reduces production efficiency and increases manufacturing costs.

Most conventional fishing sinker molds employ simple and non-optimized cooling channel configurations, which are designed without detailed thermal analysis. As a result, the cooling performance of the mold is not maximized, and thermal gradients remain high during the solidification process. Therefore, a systematic thermal analysis and optimization of cooling channel design is required to improve heat transfer efficiency, reduce temperature variations, and enhance the overall quality of aluminium fishing sinker castings.

2. METHODOLOGY

This study employs a numerical approach to analyze and optimize the thermal performance of an aluminium fishing sinker mold using cooling channel design. The methodology consists of mold modeling, material property definition, thermal boundary condition setup, numerical simulation, and performance evaluation. Each stage is conducted systematically to ensure accurate analysis of heat transfer and cooling efficiency within the mold.

2.1 Mold Geometry And Cooling Chanel Design

The geometry of the aluminium fishing sinker mold is designed based on the typical shape and dimensions commonly used in small-scale aluminium casting applications. The mold consists of a cavity corresponding to the fishing sinker shape and internal cooling channels embedded within the mold body. Several cooling channel configurations are considered by varying the channel layout, length, and position relative to the mold cavity. These variations are intended to evaluate the influence of cooling channel design on temperature distribution and heat removal performance.

2.2 Material Properties And Thermal Parameter

The mold material is assumed to be aluminium due to its high thermal conductivity and widespread use in casting applications. Relevant thermal properties such as thermal conductivity, density, and specific heat capacity are defined based on standard aluminium material data. The cooling fluid properties, including density, specific heat, and inlet temperature, are also specified to represent realistic cooling conditions. These parameters are applied consistently throughout the numerical simulation to ensure reliable thermal analysis.

3. RESULT

This section presents the numerical simulation results of the aluminium fishing sinker mold with different cooling channel designs. The results focus on temperature distribution, cooling time, and temperature gradient obtained from the thermal analysis.

3.1 Temperature Distribution In The Aluminium Mold

The temperature distribution of the aluminium fishing sinker mold is obtained from numerical simulation under specified thermal boundary conditions. In the initial cooling channel configuration, higher temperatures are observed near the mold cavity region. The temperature contour shows non-uniform distribution across the mold body during the cooling process.
For the modified cooling channel configuration, the temperature distribution within the mold is more evenly distributed. The temperature near the mold cavity is reduced compared to the initial configuration, and the overall temperature field shows a more uniform pattern throughout the mold. The numerical values of temperature gradients for both configurations are presented in Table 1.

Table 1: Simulation parameters for aluminium fishing sinker mold.

Parameter	Value	Unit
Mold material	Aluminium	–
Thermal conductivity	xxx	W/m·K
Cooling fluid inlet temperature	xxx	°C
Cooling channel diameter	xxx	mm
Cooling fluid velocity	xxx	m/s

For the modified cooling channel configuration, the temperature gradient distribution is lower and more evenly distributed throughout the mold.

4. DISCUSSION

The results obtained from the numerical simulation demonstrate clear differences in thermal behavior between the initial and modified cooling channel designs in the aluminium fishing sinker mold. Variations in temperature distribution, cooling time, and temperature gradient highlight the influence of cooling channel configuration on mold thermal performance. The more uniform temperature distribution observed in the modified cooling channel design indicates improved heat removal capability within the mold. By positioning the cooling channels more effectively relative to the mold cavity, heat is extracted more evenly from the molten aluminium during solidification. This uniform cooling condition is essential for maintaining consistent solidification rates throughout the mold and reducing localized overheating.

The reduction in cooling time achieved by the modified cooling channel design reflects enhanced cooling efficiency. Faster heat extraction allows the mold to reach the target temperature in a shorter period, which can increase production efficiency and reduce cycle time in aluminium casting processes. Shorter cooling cycles also contribute to improved mold productivity without compromising casting quality.

In addition, the lower temperature gradients observed in the optimized cooling channel configuration suggest a reduction in thermal stress within the mold. High thermal gradients are often associated with internal stress development and potential casting defects. Therefore, minimizing temperature gradients through effective cooling channel design plays a crucial role in improving the reliability and durability of aluminium fishing sinker molds.

Overall, the discussion confirms that thermal optimization through cooling channel design significantly enhances mold performance. The numerical findings support the use of optimized cooling channels as an effective approach to improve temperature uniformity, cooling efficiency, and casting quality

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in aluminium fishing sinker mold applications.

5. CONCLUSION

This study has presented a thermal optimization analysis of an aluminium fishing sinker mold using different cooling channel designs through numerical simulation. The investigation focused on evaluating temperature distribution, cooling time, and temperature gradient to assess the thermal performance of the mold.

The results indicate that the cooling channel design has a significant influence on the thermal behavior of the aluminium mold. The modified cooling channel configuration provides a more uniform temperature distribution, reduces cooling time, and lowers temperature gradients compared to the initial design. These improvements contribute to enhanced cooling efficiency and better thermal control during the solidification process.

Based on the findings, thermal optimization through proper cooling channel design is an effective approach to improve mold performance and casting quality. The outcomes of this study can serve as a reference for the design and optimization of cooling systems in aluminium casting molds, particularly for fishing sinker applications.

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