The System for Evaluating Fluidity and Solidification Characteristic of Alloy Melt

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The fluidity and solidification characteristic of alloy melt will affect the casting quality directly. It is necessary to build up a system to evaluate fluidity and solidification characteristic simultaneously. A new system, which consists of fluidity evaluation unit and solidification characteristic evaluation unit, is developed. The fluidity of alloy melt is evaluated by melt flow velocity and flow length in a special mould and the solidification characteristic of alloy melt includes solidification temperature range, linear shrinkage, thermal stress and hot tearing tendency. In the paper, the principle of measuring various parameters, the key techniques of hardware and software design are discussed and the application results are also analyzed.

Keywords: fluidity, solidification characteristic, evaluating system

Introduction

The casting quality, such as shape integrity, edge sharpness and acceptable properties, is attached much importance to the mold-filling capacity and solidification characteristic of alloy melt, the evaluation of which has accordingly attracted plenty of investigation in depth.

In the practice home and abroad, fluidity is always used to characterize the mold-filling capacity and to provide a basis for the determination of the processing parameters, like gating system, mold structure, etc.[1-4]. Flow length of the fluidity spiral sample or the vacuum fluidity test sample is conventionally adopted to evaluate the fluidity of alloy melt. Based on this, various methods and units have been developed to measure the fluidity more precisely and automatically. M.Di Sabatino reported higher precision acquired in fluidity test using plunger pouring to get good command of pouring temperature and pressure[5]. Xu Lin from Taiyuan University of Technology developed a new device named ALWY-1 to test the resistance change of the resistance wire wrapped by alloy melt[6], which could reflect the flow length change of the test sample. Making use of the conductivity of melt, Li Fengjun from Tsinghua University obtained instantaneous flow velocity and flow length of the melt in the mold-filling process by testing the breakover frequence and holding time of the contacts that burried into cavity in advance [7]. In addition, there are relevant reports on the application of high-speed photography method and X-ray-based observation[8-12].

In the design of casting structure and casting technology, the consideration of linear shrinkage, thermal stress and hot tearing tendency is very important. Over a few past years, scholars home and abroad have made profound investigation on various measurement methods and instruments and acquired certain success in the test of solidification temperature range, linear shrinkage, thermal stress and hot tearing tendency. The instrument function has developed from single-parameter to comprehensive multiple parameters, and data processing from X-Y recorder to SCM and to IPC [13-15]. The instrument developed by Li Mingdi et al from Shandong Institute of Architecture & Engineering has been applied in laboratory for teaching experiment of cast alloy[16]. Zhang Jiafeng et al from Tsinghua University have tested the stress change of aluminum alloy using self-made device[17]. On the basis of ZQS-2000 tester, Gao Xinsheng from Wuhan University of Science and Technology has developed a new system for measuring linear shrinkage and hot tearing tendency of cast alloys [18]. The foundry test and control lab in Harbin University of Science and Technology developed a new type tester for measuring the linear shrinkage, thermal stress and hot tearing tendency of cast alloys[19-20].

On the basic of analyzing the existing apparatus, the authors developed a new system, which consists of fluidity evaluation unit and solidification characteristic evaluation unit, to provide a reference for designing new casting material and optimizing foundry technology, and also supplying universities or colleges with an experimental platform.

Characterization parameters and testing methods for the fluidity of alloy melt

The fluidity of alloy melt refers to its flow length in the standard mold. The flow length, however, reflects only the final length under certain conditions but no instantaneous mold filling information. Actually, according to Reynolds, cast alloys with the same filling capacity under the identical filling velocity can either be turbulence or laminar flow because of their different viscosity. Therefore, an integrated data consisting of flow length and transient flow velocity is a desired

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parameter. For improving the deficiency of present testers, the authors developed a visual dynamic evaluation system within which the traditional drag flask was replaced by transparent heat-resistant quartz plate, and a common camera was used to record the flowing process of melt sample. Therefor the instantaneous velocity and flow length as well as the final flow length could be obtained by image recognition and analysis.

In traditional image acquisition and data processing system, CCD camera is used for capturing images, internal storage or screen for saving images and line scanning techniques for identifying feature points of the images, which requires a special image acquisition card and the corresponding software. As shown in Fig.1, the picture is progressively scanned from left to right and bottom to top, and the pixel values are recorded simultaneously. The characteristics of the image are ultimately depicted by feature points, which are determined by pixel values in discrepant gray scale that is recognized by special software. However, when the image is identified in this way, tiny change will take place, and the scanning for the whole image and the analysis point by point are needed, which increases the processing time undoubtedly.

During the overall visualization test process, there is an important available objective condition—the previous region of variation, that is to say, the only variation is the flowing track of the melt. The new method only recognizing the changed regions is distinguished from traditional methods scanning the whole region, which will accelerate the data processing and improve the precision.

After the origin coordinate is located, the flow-track equation of alloy melt can be drawn, and the length from every point of orbit to the origin can also be calculated in accordance with the Archimedean formula. Therefore, the common camera is easy to be used to capture the flow along certain track. Fig.2 is the sketch of the system being filled. Cycle detection of the initial point (point 1) is made at first when its pixel value is changed, and then the system begins to distinguish the next trace point(point 2) which has been calculated previously. Meanwhile, the instantaneous flow velocity and flow length are computed and the flow time and coordinate values of point 1 and point 2 are drawn simultaneously. To distinguish, and to calculate until no alteration in the current point could be observed or until the evaluation of point 31. It is the known locus equation that makes it convenient to extend the monitor point and to upgrade the calculation accuracy.

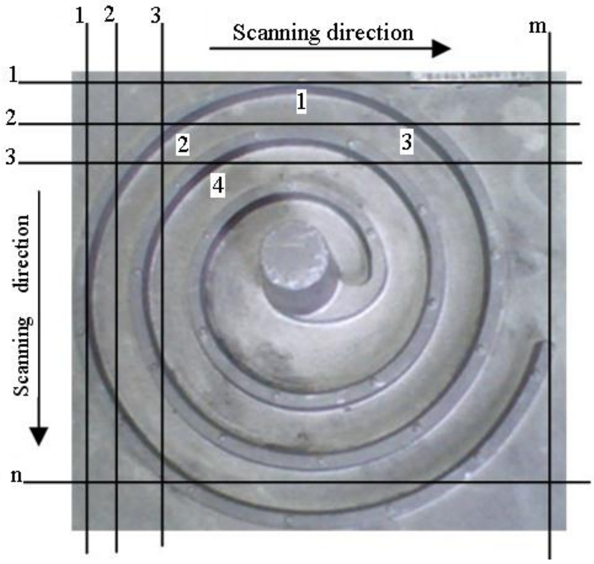


Fig.1: Order of the points based on scanning

Fig.2: Order of the points in filling process

Parameter and Method of Evaluating Solidification Characteristics of alloy melt

Solidification characteristics including solidification temperature range, linear shrinkage, thermal stress and hot cracking tendency are significant parameters for influcing the casting and solidification process. The solidification temperature range and velocity will determine the solidification mode. The narrow temperature range leads to skin solidification tendency and the wide volume solidification. To guarantee the casting quality under a given solidification temperature range, the solidification mode can be controled by optimizing the casting process and specific solidification velocity. Similarly, particular design of casting process is also an effective means for ensuring the size and properties of castings within the foregone information in melt shrinkage, thermal stress and hot cracking tendency.

Comprehensive multi-parameter analysis of alloy melt solidification characteristics includes traditional single parameter test for linear shrinkage, thermal stress, hot cracking tendency, and temperature range. The system structure based on the method mensioned above is shown in Fig.3. The hardware mainly comprises unloading unit, positioning unit, modeling unit, thermal analysis sampler, sensor group and the data acquisition and processing unit.

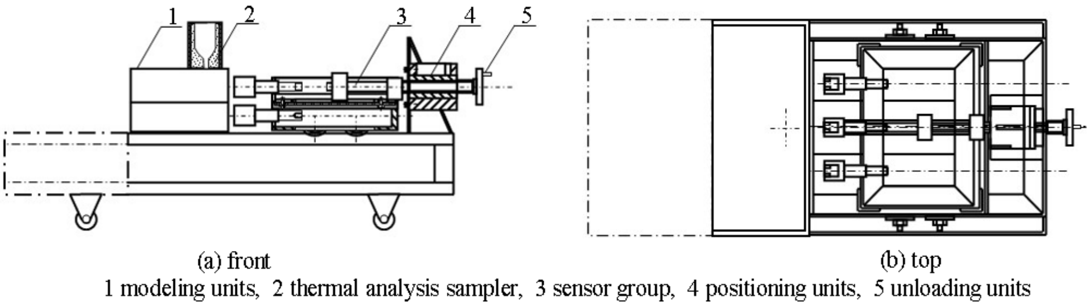


Fig.3: The structure of evaluating solidification characteristics

Positioning unit is used to fix position of modeling unit and sensor connector. Sensors are connected to the specimen through the connecting rod, within which thermal elements and signal transmission lines are embedded for measuring real-time temperature. Besides, positioning unit is also used to change test functions.

Unloading unit makes it easy to remove solidification specimen after testing. In hot cracking tendency testing position, the specimen is connected to the positioning unit and the fixed clamps at each end respectively. During solidification process, it is difficult to depart the specimen from either positioning unit or fixed clamps because of the contraction stress generated by linear shrinkage, however, it can be released easily by the rotating the hand wheel and the conjoint screw rod in the unloading unit.

Modeling unit is composed of flask and mould. The three detachable samples which can be fixed on the plate by the location pins are designed according to the test standard, and they are used for measuring the linear shrinkage, thermal stress and hot cracking tendency respectively. The horizontally parted flask is made up of the top and bottom. Various parameters can be tested using the same flask and plate by replacement of the corresponding samples. The thermal analysis sampler is also served as a sprue cup. The measurement for solidification temperature range is obtained after the thermal analysis curve is recorded.

Sensor group mainly includes three type BK-2Y pressure sensors and a type WDL25 displacement sensor, which convert the stress and displacement to electrical signals respectively. The measurement for linear shrinkage, thermal stress and hot cracking tendency are differentiated by different samples and sensors.

Data acquisition and processing unit is used to collect multiparameters including alloy solidification temperature range, linear shrinkage, stress and cracking tendency, and to analyze the acquired data and finally to display the testing results on the screen or save the database. Data acquisition module ADAM4017 and ADAM4018M are adopted to acquire the signals of displacement, stress and temperature. These signals will be sent to the computer through the communication interface module ADAM4520.

System Construction for Alloy Melt Fluidity and Solidification Characteristic Evaluation

Based on the testing principles and realization methods of testing alloy melt fluidity and solidification characteristics, a new system combined both fluidity tester and solidification tester was developed and a flexible software was designed. The mechanism structure of the system is shown in Fig.4. The left side is the fluidity test unit including gating unit, insulated gate, sand sample and image acquisition unit, and the right side is solidification characteristics evaluation unit.

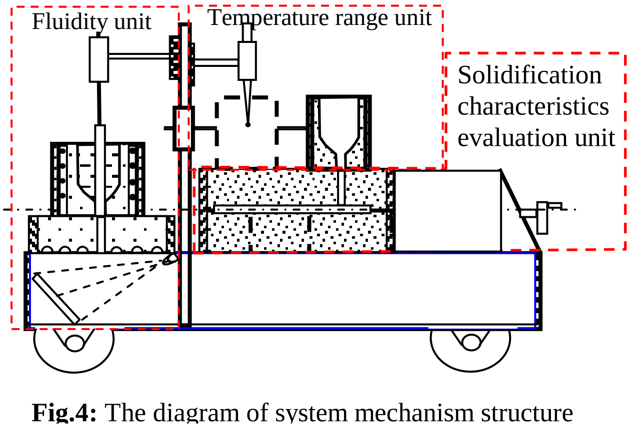


Fig.4: The diagram of system mechanism structure

In the fluidity test unit, the pouring temperature and static pressure of the sample melt can be effectively controled via an electronic lock and temperature measuring device. The substitute quarts glass served as bottom flask needs to be modified through a special treatment. The main program to evaluate the fluidity is shown in Fig.5.

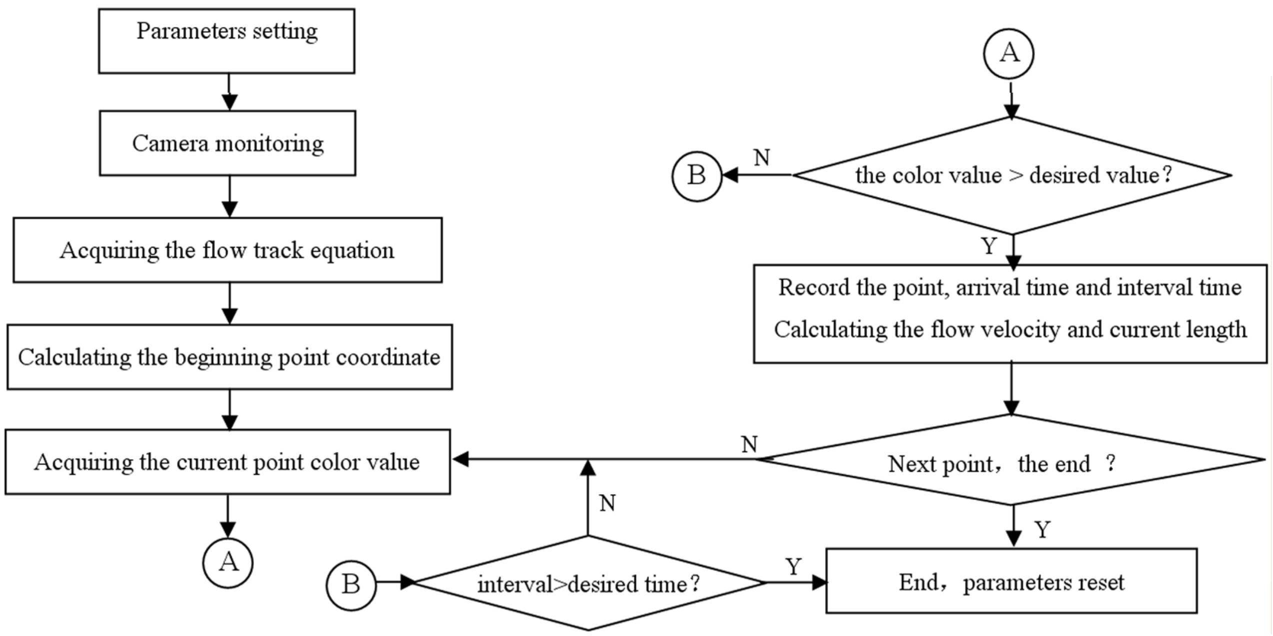


Fig.5: Main program of calculating the flow velocity and length based on flow track

The Solidification characteristics test unit is used to measure the solidification temperature range, linear shrinkage, thermal stress and hot cracking tendency simultaneously. Hereon, the sprue cup was also used to hold the thermal analysis specimen for the solidification temperature range test. After the alloy melt fulfilled the mould, the sprue cup is pushed to the preset position and the thermocouple is fallen into the cup to test the temperature range.

Delphi language is adopted to compile the software system, which mainly includes solidification characteristics test module and fluidity test module. Multi-thread technology is used in the program in order to display the real-time results and testing curve or image.

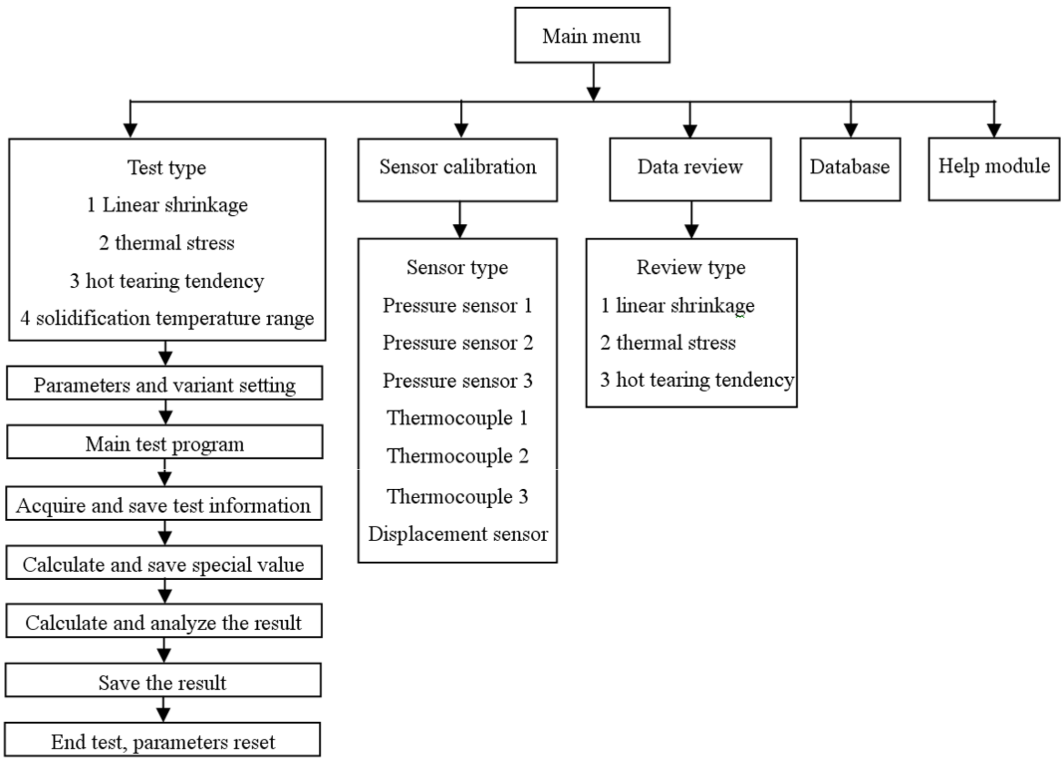


Fig.6: Framework of solidification characteristics test module

Fig.6 depicts the framework of solidification characteristics test module, which is mainly composed of five parts, namely the test module, sensor calibration module, historical data view module, database module and help module. The main interface of solidification characteristics is shown in Fig.7.

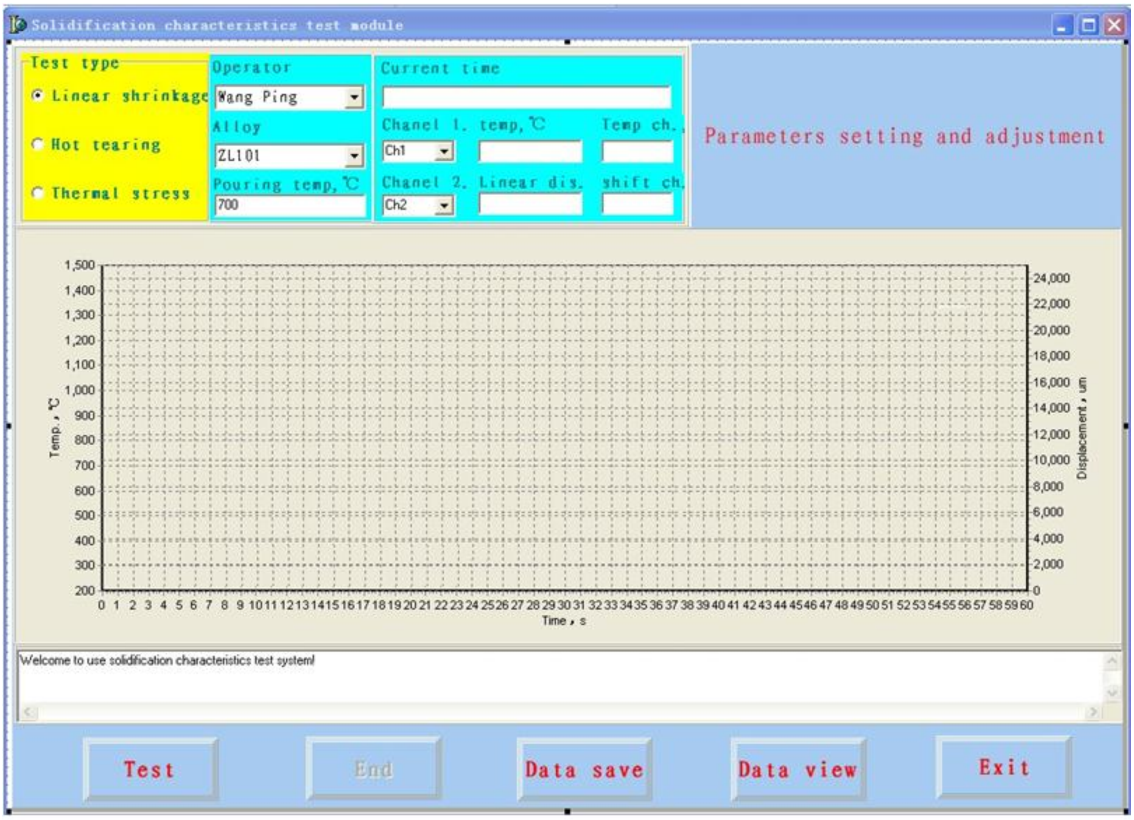
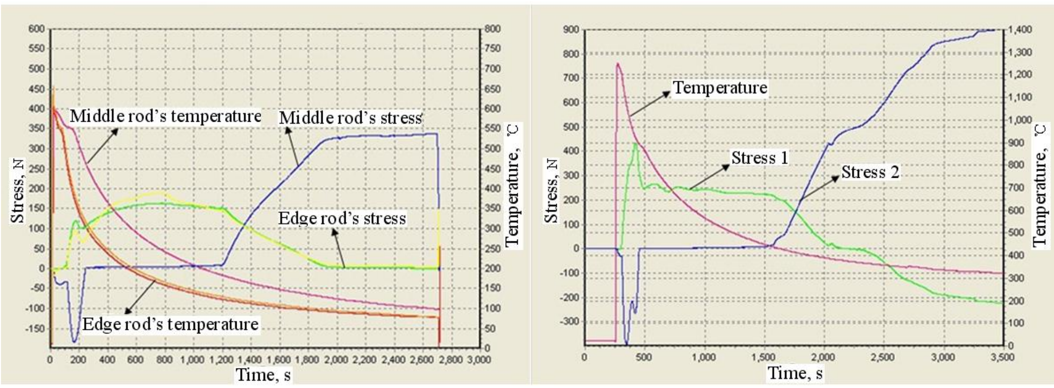


Fig.7: Main program interface of solidification characteristics test module

Practical Experiments on Evaluation System

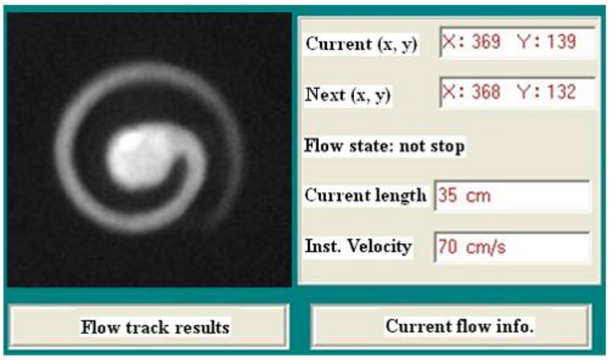
A comprehensive system to evaluate the fluidity and solidification characteristics of alloy melt was adopted to test the fluidity, solidification temperature range, linear shrinkage, thermal stress and hot cracking tendency in the lab, and the experimental results are shown in Fig.8 and Fig.9. The results show that the developed evaluation system has the error of 2℃ in temperature range test, 0.5% in linear shrinkage test, 2% in thermal stress test, 2% in hot tearing tendency test and less than 1% in final flow length test comparing with the practical value.



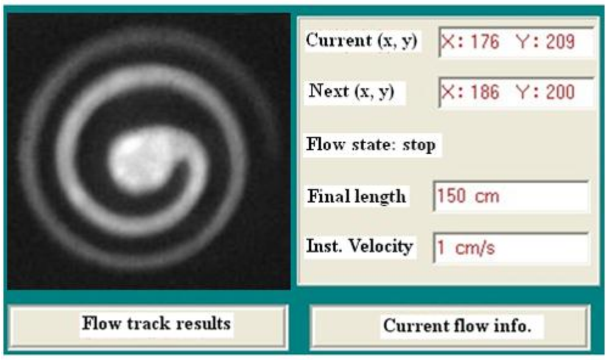
(a) ZL114

(b) gray iron with 3%C

Fig.8: Stress-time relation of different alloys



(a) Filling process



(b) Filling end

Fig.9: Fluidity evaluation program interface

Conclusions

The comprehensive and accurate evaluation on fluidity and solidification characteristics of alloy melt is very important in practice. The experimental results indicate that the fluidity of alloy melt can be real-time and roundly evaluated by tracing track and computer recognition method. The high-precision comprehensive evaluation on the solidification characteristics can be realized by the novel desin of compound sampling structure, stress-unloading unit and dual purpose sprue cup.

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