Computer Aided Engineering Design of Power Injection Molding Process for Dental Scaler Top Mold Design

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Abstract

Powder Injection Molding (PIM) has recently been recognized as an advanced manufacturing technology for low-cost mass production of metal or ceramic parts of complicated geometry. With this regards, design technology of dental scaler tip PIM mold, which has complex shape, with the help of computer-aided analysis for powder injection molding process was developed. Compter aided analysis results, such as filling pattern, weldline formation, and air vent position prediction were investigated and eventually showed good agreements with experimental results.

Keywords : Dental Scaler Tip, Powder Injection Molding(PIM), Mold Design, CAE Analysis

1. Introduction

Powder Injection Molding (PIM) has recently been recognized as an advanced manufacturing technology for low-cost mass production of metal or ceramic parts of complicated geometry. With this regards, design technology of dental scaler tip PIM mold, which has complex shape and a slim core pin of 0.6 mm diameter, with the help of computer-aided analysis for powder injection molding process was developed. Compter aided analysis results, such as filling pattern, weldline formation, and air vent position prediction were investigated and eventually showed good agreements with experimental results.

2. Experimental and Results

Dental scaling system in dentistry generates ultrasonic vibration on dental scaler tips to remove tartar on teeth and to treat gums [Fig. 1]. These dental scaler tips are manufactured by maching process, mainly due to its shape complexity. Machining process has an advantage in the accuracy of the scaler tips, but requires high cost due to the many processing steps. Therefore, it is difficult to keep machining process to manufacture a lot of variations of the dental scaler tip. In order to solve the problem, the PIM process with the aid of CAE analysis for the dental scaler tip was introduced to replace machining process [1]. In this study, the dental scaler tip was redesigned for the PIM process. As well as the product, the mold and process was designed with the aid of CAE analysis. The design process with the CAE analysis is presented in this article.

Dental scaler tip is basically attached to an ultrasonic vibrator with thread at the bottom. The dental scaler tip has a nozzle at the bottom of the edge as a coolant flowpath. To make the nozzle, a slim core pin is used in the mold, causing hassle in the mold design as shown in Fig. 2. Injection molded scaler tips with LDPE and the PIM feedstock containing STS316L powder, and a sintered product in Fig. 3. In order to make such a small product with a high accuracy by the PIM process, it was necessary to design the mold and to find an optimum processing condition with the aid of CAE analysis.

MPI from Moldflow™commercial was used as the CAE analysis tool in this study [2]. The physical and rheological properties of the PIM feedstock with STS316L powder were evaluated by experiments and put into the software as a user-defined material database. Fig. 4 shows the maximum injection pressure as a function of filling time. The maximum injection pressure showed a U-shaped curve with a minimum at 0.4~1.0 seconds. The minimum pressure of 31.4 MPa was obtained numerically at 0.7 seconds, indicating that the optimal injection time is 0.7 seconds [2]. However, the actual injection time was set to 0.4 seconds with consideration of a shorter cycle time. The maximum pressure was obtained with a constant injection speed. An analysis was conducted to find an optimum ram profile. The objective of the analysis was maintaining the melt front velocity (MFV) consistent throughout the filling stage. Fig. 5 shows recommended ram profile based upon the result of the MFV analysis.

As the dental scaler tip required very small core pin of 0.6mm diameter, the core pin bending problem might occur during injection molding process. Therefore, the core pin bending was checked in the CAE analysis, as shown in Fig. 6. If a core pin is bent due to a high injection pressure, the flowpath inside the scaler tip could not be made in perfect shape. As shown in Fig.10, structural analysis to identify the

bending behavior of the core pin during injection molding process was conducted [3, 4].

Fig. 7, 8 and 9 show the results of shot-shot experiment to investigate the injection mold filling process. The location of a weldline was identified in the results in Fig. 8 and Fig. 9. The weldline location in the sample of the PIM feedstock was identical to the one in LDPE sample, but the mold filling pattern was slightly different. The mold filling pattern of the CAE analysis for the PIM process with STS316L feedstock showed a better agreement.

3. Summary

A dental scaler tip was redesigned for the PIM process. It was difficult to mold the dental scaler tip due tothe complex shape with a slim core pin of 0.6 mm diameter. In order to make the dental scaler tip by the PIM process successfully, various aspects in the mold design and the molding process should be taken into consideration. In this study, CAE analysis was utilized to examine possible problems in the mold design and the molding process.

4. References

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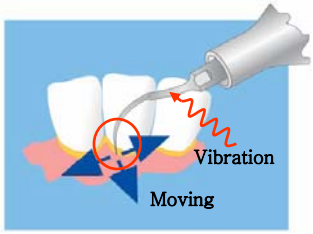


Fig. 1. Schematic view of dental scaler usage.

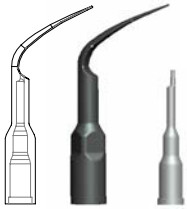


Fig. 2. Final design of dental scaler tip.

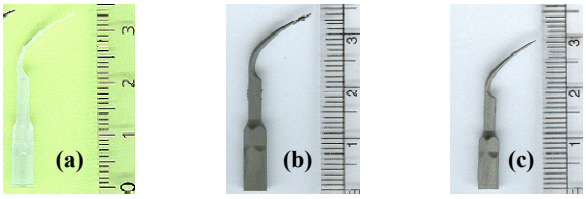


Fig. 3. Injection molded dental scaler tip with(a) LDPE, (b) PIM feedstock, (c) that of after sintering.

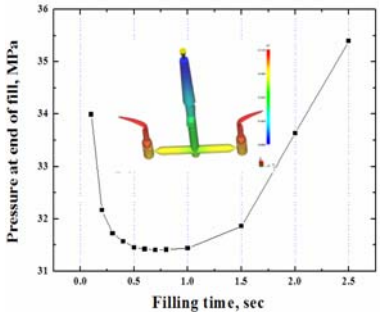


Fig. 4. Pressure at end of fill vs. Filling time (Optimum filling time = 0.7sec).

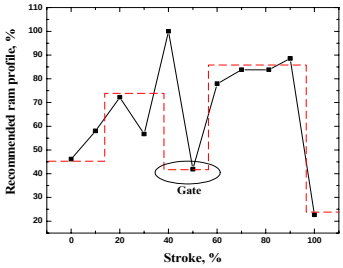
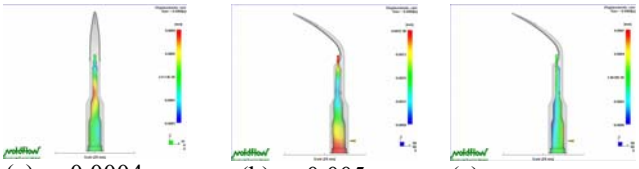


Fig. 5. Recommended ram profile (i.e. injection velocity profile).



(a) x=0.0004mm (b) y=0.005mm (c) z=0.000755mm

Fig. 6. Distribution of core deflection (scale factor=100).

Fig. 7. Short shot experiment of dental scaler tip using LDPE.

Fig. 8. Short shot experiment of dental scaler tip using PIM feedstock with STS316L.

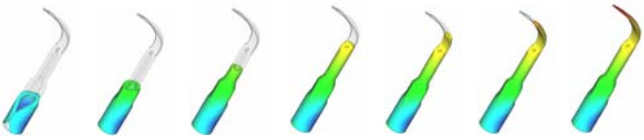


Fig. 9. Melf front advancement of dental scaler tip mold using CAE analysis.