DEWAXING OF ABS RAPID PROTOTYPE PATTERN FOR CERAMIC INVESMENT CASTING OF PROXIMAL HUMERUS

SOUDEH IRANMANESH

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ABSTRACT

Orthopedic implants can be defined as medical devices used to replace or provide fixation of bone or to replace articulating surfaces of a joint. Many proximal humerus bone cases require almost immediate/short lead time surgery. Thus rapid respond from the manufacture is very crucial. The manufacture of surgical implant often requires the use of machining process. Current trend shows that preform either from casting or forging is preferred to reduce machining cost and time. It is expected that by employing rapid manufacture using rapid prototyping and investment casting process could expedite the manufacturer to surgery time. The objective of this project is to evaluate the effect of dewaxing time on collapsibility characteristic of solid and hollow constructed rapid prototyped proximal humerus ABS pattern.FDM2000 machine was used to build the ABS patterns. Acrylonitrile Butadiene Styrene (ABS) P400 was used for pattern material in this study. Output responses investigated were collapsibility, expansion defects. ABS hollow and solid pattern are prepared and are subjected to dewaxing in different time and temperature. The ABS hollow and solid pattern were compared based on the dewaxing process results, ceramic shell defects. The best pattern material according to the optimum time and temperature was chosen based on the results and compared with the reference process. This study is expected to assist the investment caster to estimate the decomposition temperature and allowance required in preparing a mould from ABS pattern as well as in the initial CAD drawings to produce a final casting with minimal dimensional in accuracy. It is hoped that the outcome of this study will assist the casting industries especially in biomedical in using the advanced product support tools using CAD and RP technology for higher productivity and quality products.

ABSTRAK

Implan ortopedik boleh didefinasikan sebagai peranti perubatan yang digunakan sebagai pelekapan pada tulang atau gantian pada permukaan artikulat sendi. Kebanyakan kes tulang humerus proksimal memerlukan pembedahan yang serta merta/masa pendulu pendek. Oleh itu, respon yang pantas daripada pengilang pembuatan adalah amat penting. Pembuatan dalam pembedahan implan selalunya menggunakan proses pemesinan. Aliran semasa telah menunjukkan proses prabentuk samada daripada penuangan atau penempaan menjadi pilihan kerana dapat mengurangkan kos dan masa pemesinan. Justeru itu, pembuatan deras yang menggunakan prototaip deras dan proses penuangan lilin oleh pengilang berupaya menyegerakan masa pembedahan. Objektif kajian ini adalah untuk menilai kesan masa penyahlilinan pada sifat keboleh-runtuhan binaan prototaip deras bagi bentuk humerus proksimal ABS iaitu dalam keadaan pejal dan berongga. Mesin FDM2000 digunakan untuk membina bentuk ABS. Acrylonitrile Butadiene Styrene (ABS) P400 digunakan sebagai bahan bentuk dalam kajian ini. Respon output yang dikaji adalah keboleh-runtuhan dan kecacatan pengembangan. Bentuk ABS berongga dan pejal ini disediakan melalui penyahlilinan mengikut masa dan suhu yang berbeza. Bentuk ABS berongga dan pejal ini juga akan dibandingkan berdasarkan keputusan proses penyahlilinan dan kecacatan pada kelompang seramik. Bentuk yang terbaik pula ditentukan mengikut masa dan suhu optimum dan dipilih berdasarkan keputusan dan pembandingan melalui proses rujukan. Kajian ini dijangka dapat membantu pekerja tuangan lilin untuk menganggarkan suhu penguraian dan ruang kelegaan yang diperlukan dalam penyediaan acuan pembentuk daripada bentuk ABS dan juga didalam lukisan asal CAD. Oleh itu, tuangan dapat dilakukan mengikut ketepatan dimensi yang minimal. Selain daripada itu, hasil daripada kajian ini juga boleh membantu industri penuangan terutamanya dalam bio-perubatan yang menggunakan sokongan produk alatan termaju CAD dan juga teknologi pembuatan deras untuk meningkatkan produktiviti dan kualiti produk.

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LIST OF SYMBOLS

2D	-	Two dimensional
3D	-	Three dimensional
A	-	Ampere
ABS	-	Acrylonitrile Butadiene Styrene
C	-	Celsius
CAD	-	Computer Aided Design
CS	-	Ceramic shell
F	-	Fahrenheit
FDM	-	Fused Deposition Modeling
In	-	Inch
kg	-	Kilogram
QS	-	Quick Slice
RP	-	Rapid Prototyping
mm	-	Milimeter
gms	-	Grams
M	-	Meter
i.e.	-	In Example

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CHAPTER 1

INTRODUCTION

1.1 Background

Shoulder arthroplasty is a successful procedure for the treatment of degenerative and traumatic conditions. The use of shoulder arthroplasty has grown significantly in recent years, with an annual increase of approximately 10%. The number of primary total shoulder replacements is expected to increase by 200% to 300% by the year 2015 (Day et al., 2010).This rapid increase in the number of shoulder replacement surgeries has been accompanied by an increased need for revisions with rates of revision shoulder arthroplasty increasing from 4.5% to 7% since 1993 (Petersen & Hawkins, 1998).

The etiology of a failed shoulder arthroplasty includes problems with soft tissues, bone, infection, and component malposition or wear. The success of revision shoulder arthroplasty depends on the reason for failure, with better results after revision for component related problems, and worse outcomes after soft tissue reconstructions(Y Joshua and S. Dines, 2006).

Investment casting is a key technique among a range of modern metal casting techniques that is capable of providing an economical means of mass production of shaped metal parts containing complex features such as thin walls, undercut contours and inaccessible spaces which are difficult or impossible to create using other fabrication methods (Beeley, 1995).

Despite the wide range of applications in many industries, the standard (conventional) investment casting process practice in modern foundries has its drawbacks. High tooling costs and lengthy lead times are associated with the fabrication of metal moulds required for producing the sacrificial wax patterns used in investment casting (Sachs, Cima, & Cornie, 1990). The high tooling costs involved in conventional investment casting result in cost justification problems when small numbers of castings are required.

Investment casting could do the following (Horton, 1988):

1. Produce complex shapes that are difficult to make by other means.
2. Reproduce fine detail, high dimensional accuracy, and smooth surfaces requiring only minimal finishing.
3. Adapt to most metal alloys.
4. Allow control of metallurgical properties, such as grain size and grain orientation.

Rapid prototyping (RP) techniques are fast becoming standard tools in the product design and manufacturing industries. With the capability of rapidly fabricating of 3D physical objects, rapid prototyping has become an indispensable tool employed for shortening new product design and development time cycles (Chua , 1997; Hilton , 2000). Rapid prototyping techniques are unlimited neither by the geometry nor by the complexity of the parts to be fabricated.

In addition, rapid prototyping techniques involve no tooling or fixtures, resulting in simpler set up, lower overhead cost and shorter production lead times compared to other fabrication methods. With rapid prototyping, parts that were previously impossible or extremely costly and time-consuming to fabricate can be built with ease.

The application of rapid prototyping -fabricated patterns as substitutes for the traditional wax patterns employed in investment casting stems from the fact that rapid prototyping materials can be melted and burned out from the ceramic shell (ceramic shell casting) without damaging it (Beaman, 1997). Most commercialized rapid prototyping techniques are capable of producing such patterns that can be used directly in investment casting. Most of the limitations encountered with earlier applications of RP-fabricated investment casting patterns include damage to the ceramic shells due to excessive thermal expansion of the pattern or the release of corrosive degradation by-products during pattern burn out, which cracks or attacks the cavity surface of the shell.

Ceramic shell cracking is attributed to a mismatch in the coefficient of thermal expansion (CTE) between the rapid prototyping and ceramic materials. Most rapid prototyping materials have CTE values that are larger than the ceramic material and as such, the expansion of the pattern during heating imposes significant amounts of stress on the ceramic shell. Shell cracking occurs when the stresses imposed by the expanding pattern are greater than the modulus of rupture (MOR) of the shell material (Yao & Leu, 2000).

In some cases, residual ash can also cause defects in the final castings when present in relatively significant quantities. Also, due to the high operating and material costs of rapid prototyping techniques, the utilization of rapid prototyping techniques has been reported to be beneficial only when five or fewer castings are required (Smith, 1996).

The application of rapid prototyping techniques to produce sacrificial investment casting patterns can be classified under two methods: the direct rapid prototyping method, and the indirect rapid prototyping method. The direct rapid prototyping method covers the application of rapid prototyping techniques for producing plastic, wax or paper investment casting patterns for fabricating ceramic moulds that can be employed directly for metal casting e.g. direct shell production method (Beeley, 1995). For the indirect rapid prototyping method, alternative moulds for example is produced by silicone rubber molding in conjunction with an rapid prototyping -fabricated master pattern of the final desired casting are employed for the injection of investment casting patterns from foundry wax.

1.2 Problem Statement

Many proximal humerus cases require almost immediate/short lead time surgery. Thus rapid respond from the manufacture is very crucial. The manufacture of surgical implant often requires the use of machining process. It can either be machined from metal block or preform produced from investment casting or forging processes. Current trend shows that preform either from casting or forging is preferred to reduce machining cost and time. It is expected that by employing rapid manufacture using rapid prototyping and investment casting process could expedite the manufacturer to surgery time. Finding a new way in manufacturing process (near net-shape) and material maybe can help to manufacture that produce joint implants faster.

1.3 Project Objectives

Two specific objectives have been defined to clarify the general purpose of the project. The objectives of the project are:

i. To determine the workable flash dewaxing parameters of solid and hollow rapid prototyped ABS patterns.

1.4 Project Scope

The scopes of works for this project are as follows:

i. The flash dewaxing parameters investigated will be the firing temperature and duration.The firing temperatures and duration investigated will be in the range between 300°C and 600°C.

ii. The thickness of the ceramic investment casting mould will be of 4 layers thick with slurry viscosity of approximately 15-20s.

1.5 Overview Of The Thesis

The remainder of the dissertation is devoted to the development of the previously stated objectives. Chapter 2 describes the theoretical knowledge, literature studies, and previous researches done by the researchers that are used to be a basic ground for the project. In chapter 3, a specific methodology of the project is presented. This would include experimental set up and list of equipment that are required for the performance evaluation of the project. Results and experimental analysis from the experimental data of ABS P400 FDM-fabricated for investment casting process and casting stainless steel 316L are presented in Chapter 4. A summary of the project is given in the final chapter which includes recommendations for future work.

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