Selective Laser Sintering Process Management Using a Relational Database

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ABSTRACT

With more and more materials used in the Selective Laser Sintering (SLS) process, it is becoming necessary to use a database to manage the process efficiently. In this paper, a relational database for the SLS process is described. The database includes powdered material data, sintering parameters, machine characteristics, mechanical properties and surface quality of prototypes. Use of this database will make it is easy to store and retrieve processing information and make decisions for planning the SLS. This paper will go on to describe how the database can be extended to include other RP technologies.

Keywords: Rapid Prototyping (RP), Selective Laser Sintering (SLS), Database Management Systems (DBMS), Process Planning.

INTRODUCTION

With the rapid development of modern science, computer technology plays a more and more important role in manufacturing engineering. Many advanced technologies such as computer-aided design/computer-aided manufacturing (CAD/CAM), computer integrated manufacturing (CIM), robotics, concurrent engineering (CE), and flexible manufacturing systems (FMS) have been applied to manufacturing industry. Time-to-market becomes a key factor to determine the survival of a manufacturing company in the global market. Meanwhile, due to globalization of information technology (IT), CIM is seen as a key competitive strategy for future advanced manufacturing systems in the 21st century.

Being regarded as a major technological breakthrough after NC technology, rapid prototyping (RP) is receiving more and more attention from manufacturers and researchers. Also based on computer technology, RP can produce any complex object in a few hours directly from a computer model without any part-specific tooling or knowledge [1]. Now, a lot of companies are using RP to help speed up their product's time-to-market.

Selective laser sintering (SLS) is a premier RP process with a wide range of materials that can be fabricated into prototypes for conceptual, functional, and tooling applications. With increasing use in the manufacturing chain, it is becoming necessary to use a database to manage the process efficiently. In this paper, a relational database for management of the SLS process is described. Information elements stored in the database include powdered material data, sintering parameters, machine characteristics, prototype's mechanical properties and surface quality. Online exploitation of databases can make it is easy to store and retrieve processing information and make decisions for planning the use of SLS equipment.

FUNDAMENTALS OF RELATIONAL DATABASE

In the simplest sense, a database is a collection of records and files that are organized for a particular purpose [2]. The basic element in the database is called an entity. There are three kinds of relationships between entities: one-to-one, one-to-many, and many-to-many (Figure 1).

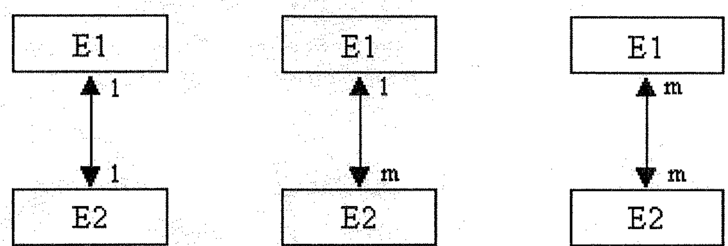


Figure 1 Three kinds of relationships between entities

Nearly all modern database management systems (DBMS) store and handle information using the relational database management model. The term relational stems from the fact that each record in the database contains information related to a single subject and only that subject. Data concerning two classes of information can be manipulated as a single entity based on related data values. This structure is popular among CIM systems because it is relatively easy to design and modify data structures.

A relational database management system (RDBMS) has three main types of capabilities:

- Data definition—to define what data will be stored in the database, the type of data, and how the data is related. In some cases, it is also needed to define how the data should be formatted and how it should be validated.
- Data manipulation—to handle the data in many ways such as to select data fields, to filter the data, and to sort it.
- Data control—to define who is allowed to read, update, or insert data. In many cases, it is also defined how data can be shared and updated by multiple users.

The relational database management systems can be built with many commercial software packages like Oracle, dBASE, FoxPro, and Access. In our research project, the database management system for the selective laser sintering process has been built with Access97.

Within an Access database, the main objects are tables, queries, forms, reports, macros, and modules [3]:

- Table—to store the data for the tasks. It is made up of columns, or fields, each of which contains a specific kind of data, and rows, or records, which collect all the data about a particular object.
- Query—to provide a custom view of data from one or more tables. It can be defined to select, update, insert, or delete data. Access stores every query as a Structured Query Language (SQL) command.
- Form—designed for data input or display or for control of application execution.

- Report—designed for formatting, calculating, printing, and summarizing selected data.
- Macro—a structured definition of one or more actions to perform in response to a defined event.
- Module—custom procedures using the Visual Basic for Application (VBA) language. It can be called from anywhere in the application, or directly associated with a form or a report to respond to events on the associated form or report.

Figure 2 shows the main objects and their relationships in Access.

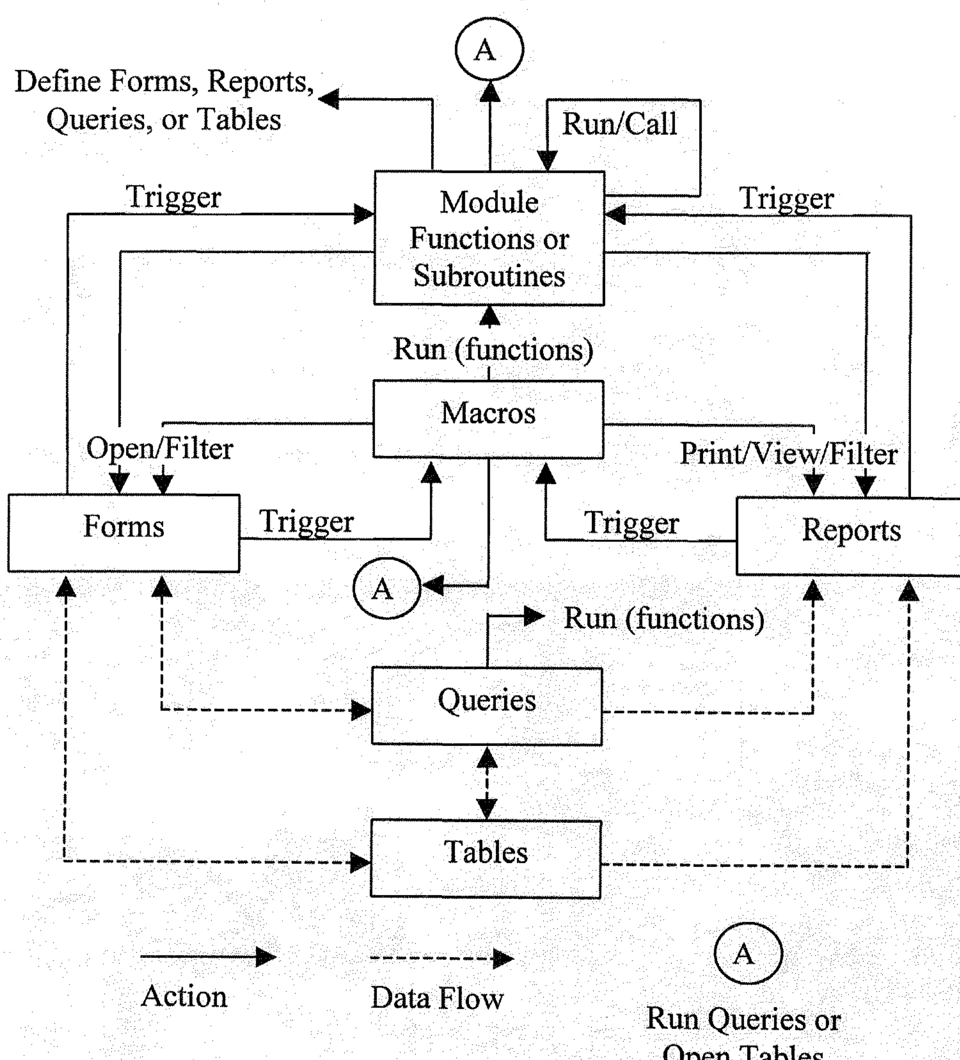


Figure 2 Main objects and their relationships in Access

IMPLEMENTATION

In the SLS process, the main entities are SLS machines, powdered materials, sintered prototypes, and sintering parameters. Some useful data, such as machine vendors, powdered material properties, prototype's mechanical properties and surface quality, are related with the above four entities. All entities and their relationships are stored in tables.

Table and Query Design

Table design is an important step in building a relational database. It is recommended to design many separated tables for retrieving and storing data more efficiently. Some tables and their relationships in the database are shown in Figure 3 and Figure 4.

Materials

Material ID	Initial Name	Material Name	Material Type ID	Sintering Parameters ID	Applications	Price	Physical ID	Vendor ID

Machines

Machine ID	Machine Name	Max Laser Power	Build Chamber	Position Accuracy	Max Beam Speed	Vendor ID	Price	Photo

Sintering Parameters

Sintering Parameter ID	Fill Laser Power	Fill Scan Speed	Slice Thickness	Fill Scan Spacing	X Scale	Y Scale	Z Scale	X Offset	Y Offset	Z Offset

Mechanical Properties

Mechanical ID	Young Modulus	Poisson Ratio	Tensile Strength	Impact Strength	Hardness	Elongation	Surface Tension

Figure 3 Tables defined in the database

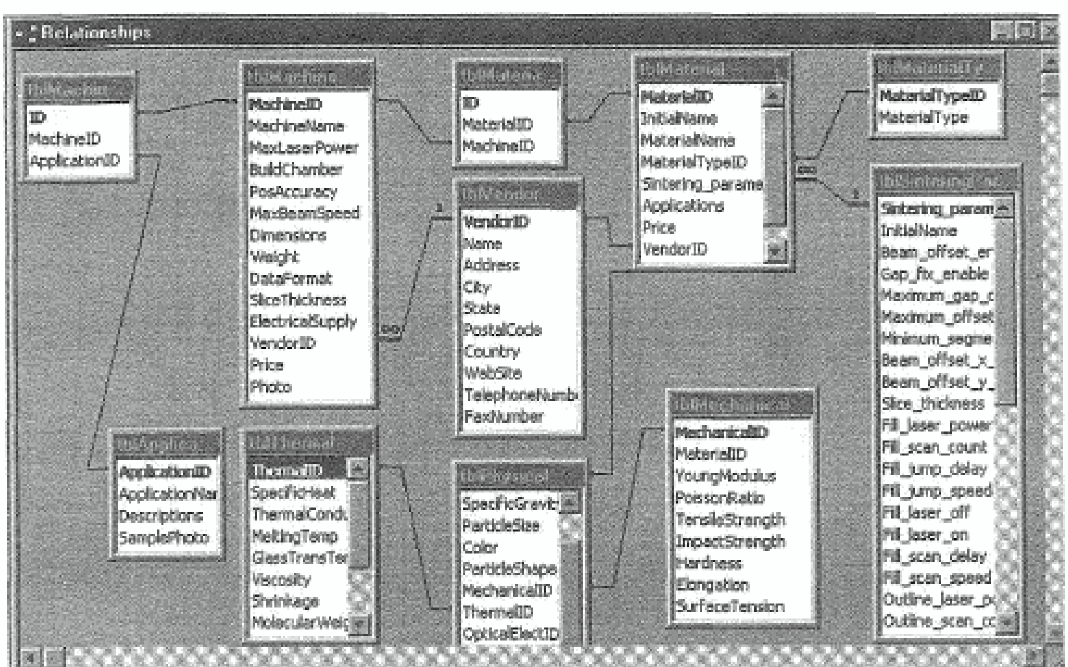


Figure 4 Relationships among tables

Queries provide a custom view of data from one or more tables. In the SLS process, the relationships of machine-to-material, machine-to-application, and material-to-application, belong to the many-to-many relationship. Using queries, it is easy to find useful information from these relationships.

Forms and Reports

Forms are designed to view and change data in the database. There are five important forms designed with respect to the four entities: frmMachines, frmMaterials, frmApplications, frmSinteringParameters, and frmPrototypeQualities. The form frmMachines provides the specifications about SLS machines. This also includes two subforms that list materials and applications available for the machine. The form frmMaterials provides specifications about the powdered materials. The form frmApplications provides the description and samples concerning applications. The form frmSinteringParameters provides sintering parameters for materials in sintering machines. The form frmPrototypeQualities provides the prototype's mechanical properties and surface quality.

Reports are designed to print data as required. Four main reports are built for printing the specifications of machines, specifications of powdered materials, sintering parameters and building profiles, and prototype's mechanical properties and surface quality.

Layout of Database

The layout of the database is shown in Figure 5.

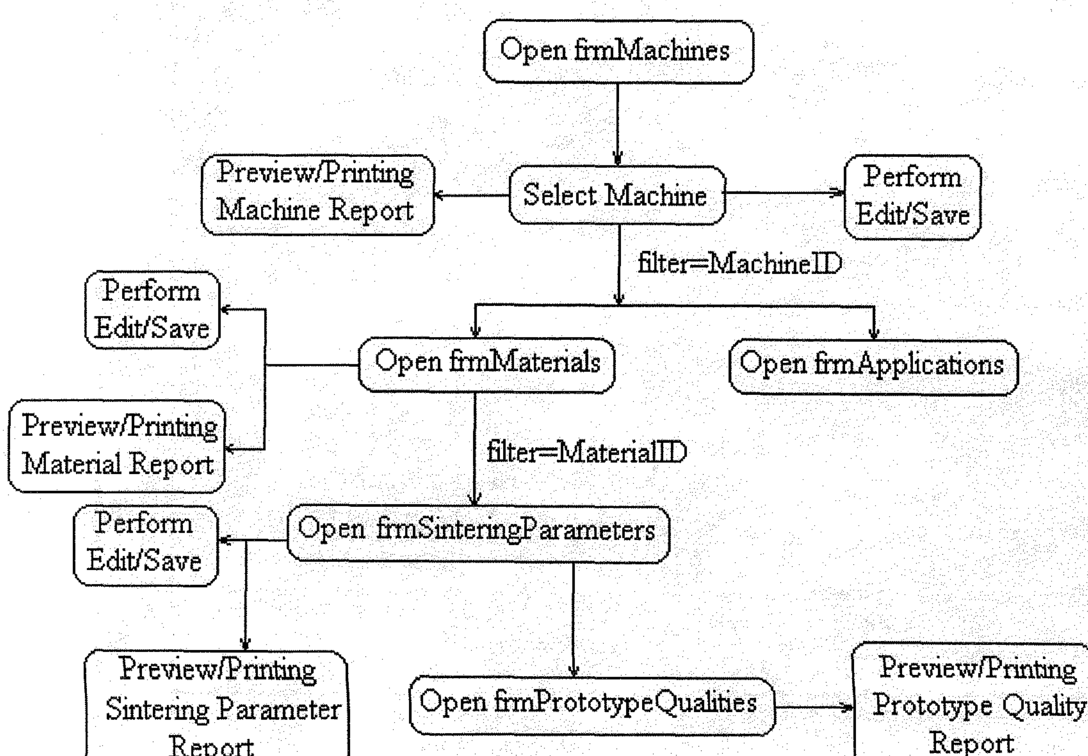


Figure 5 Layout of the database

APPLICATIONS

Currently, there are six kinds of selective laser sintering system available in the market from two vendors. More than ten powdered materials can be fabricated as visualization models, functional models, patterns for casting, and patterns for tooling. In the sintering process, a lot of sintering parameters should be set according to powdered materials. Taking the DTM sinterstation 2000 system for example, there are 31 parameters that should be set in warm-up, build, and cool-down stages, and 6 parameters related to scale and beam offset in X, Y, Z. In our previous research [4], it was found that the prototype's mechanical properties and surface quality are dependent on part orientation, powdered material properties and sintering parameters. This is important since the prototype's mechanical properties and surface quality are important factors in the design-manufacturing cycle. The database provides a convenient way to view, edit, save and print useful information. It assists the user to select machines, materials, and suitable sintering parameters according to application requirements in the design stage. Another useful application is process planning on the SLS [5].

Figure 6 to Figure 9 demonstrate use of the database.

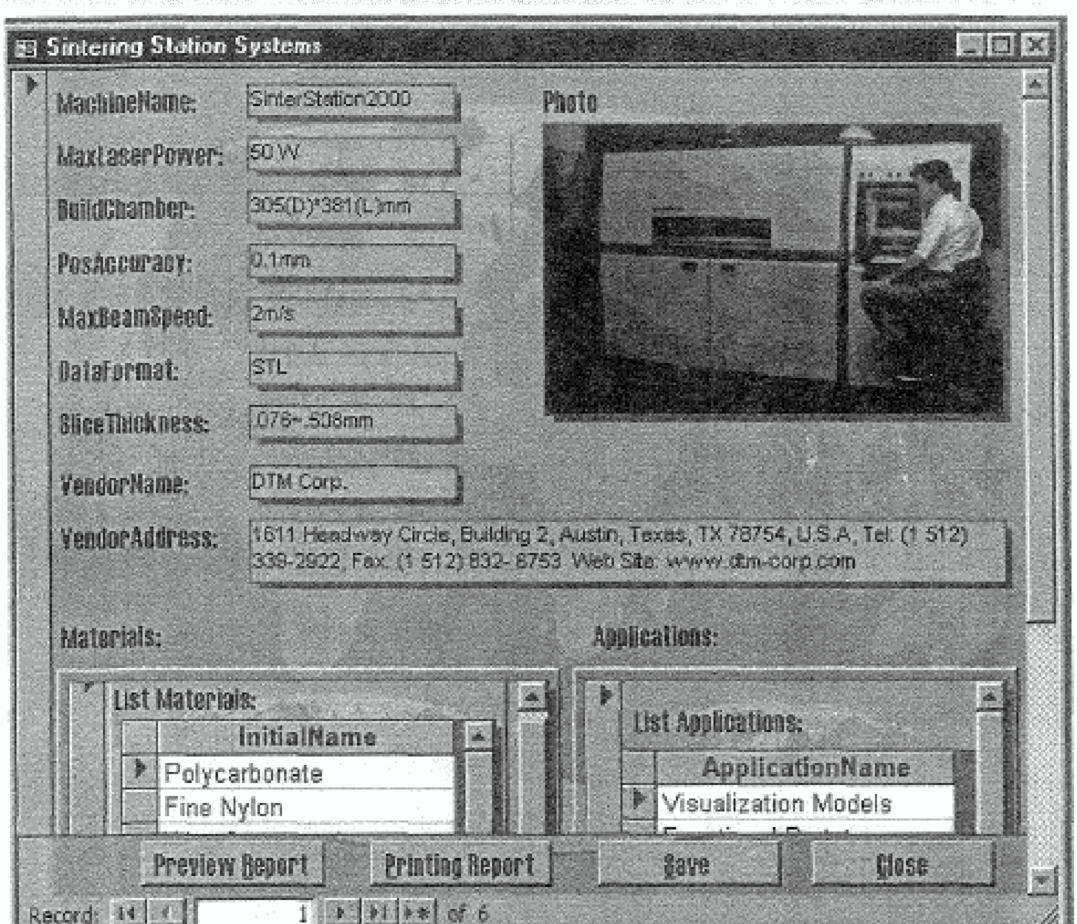


Figure 6 Form of frmMachines showing specifications, materials, and applications related to the machine

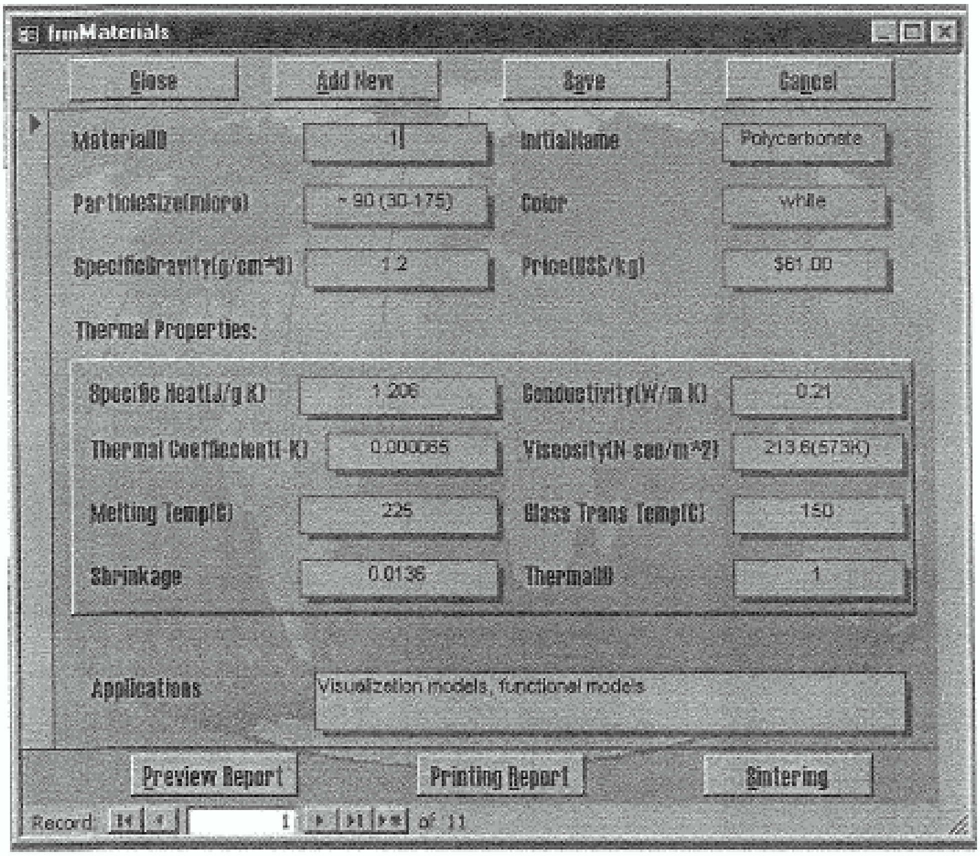
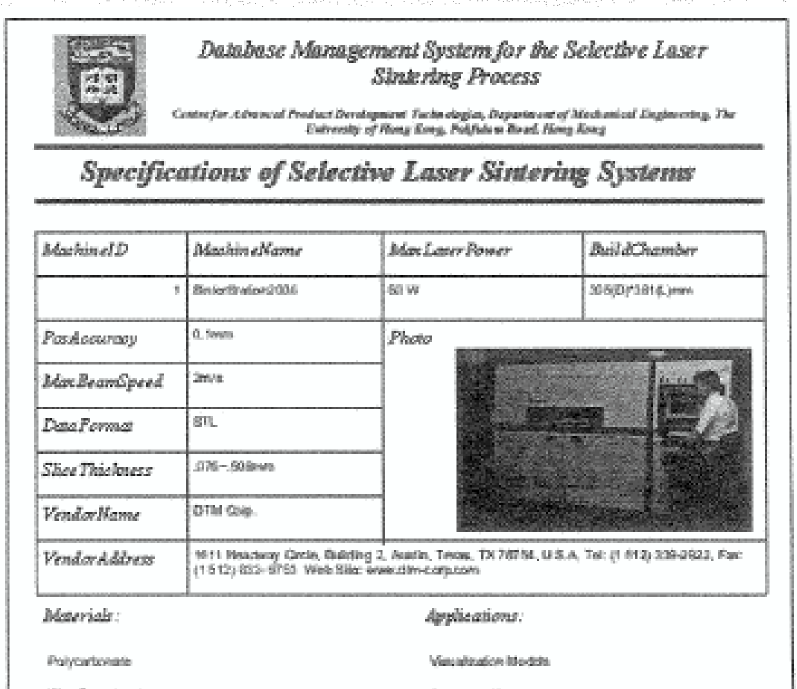


Figure 7 Form frmMaterials showing some physical and thermal properties, and applications of the material



Database Management System for the Selective Laser Sintering Process

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Specifications of Selective Laser Sintering Systems

MachineID	*MachineName*	*MaxLaserPower*	*BuildChamber*
1	SinterStation2000	50 W	305(D)*381(L)mm

PosAccuracy	0.1mm	*Photo*
MaxBeamSpeed	2m/s	
DataFormat	STL	
SliceThickness	.076~.508mm	
VendorName	DTM Corp.	
VendorAddress	1611 Headway Circle, Building 2, Austin, Texas, TX 78754, U.S.A. Tel: (1 512) 339-2922, Fax: (1 512) 832-9753 Web Site: www.dtm-corp.com	

Materials:

Polycarbonate

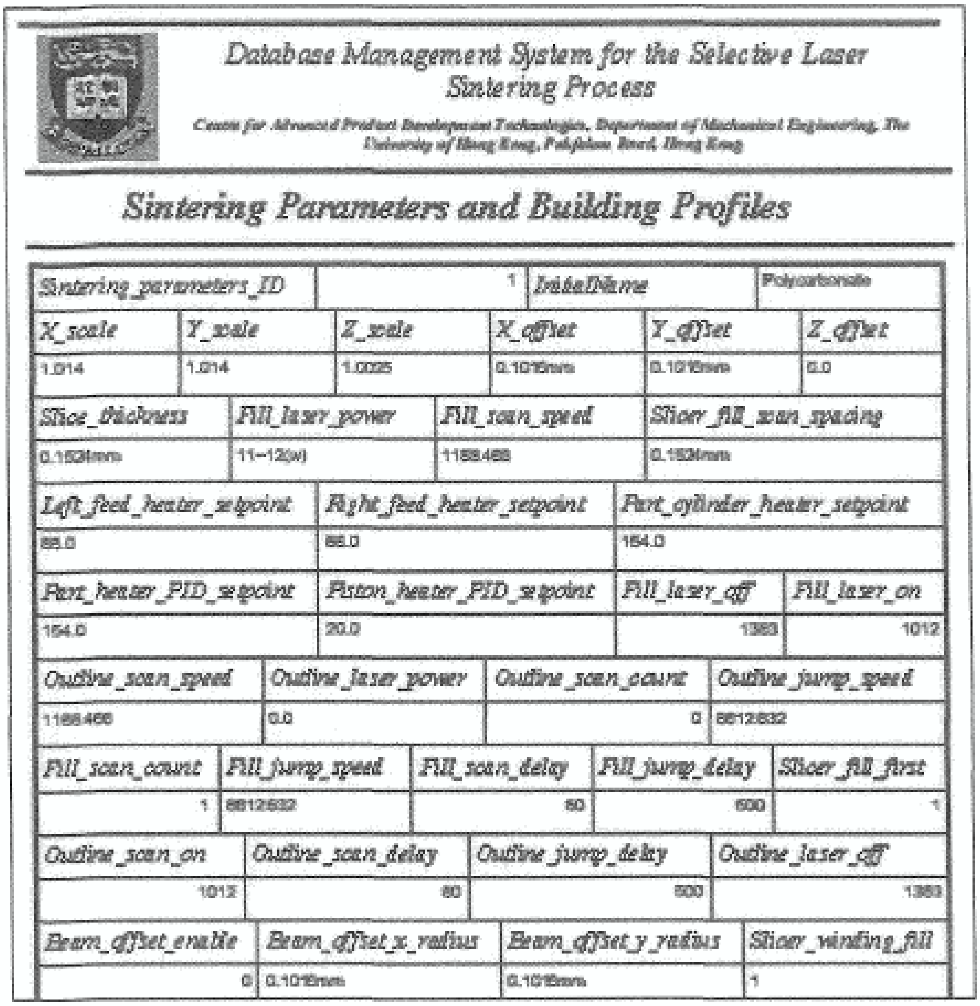
Wax Compound

Applications:

Visualization Models

Functional Prototypes

Figure 8 Report of machine specifications



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Sintering Parameters and Building Profiles

Sintering_parameters_ID		InitialName	
	1		Polycarbonate

X_scale	Y_scale	Z_scale	X_offset	Y_offset	Z_offset
1.014	1.014	1.0025	0.1016mm	0.1016mm	0.0

Slice_thickness	Fill_laser_power	Fill_scan_speed	Slicer_fill_scan_spacing
0.1524mm	11~12(w)	1168468	0.1524mm

Left_feed_heater_setpoint	Right_feed_heater_setpoint	Part_cylinder_heater_setpoint
88.0	86.0	164.0

Part_heater_PID_setpoint	Piston_heater_PID_setpoint	Fill_laser_off	Fill_laser_on
164.0	20.0	1363	1012

Outline_scan_speed	Outline_laser_power	Outline_scan_count	Outline_jump_speed
1168466	0.0	0	8812632

Fill_scan_count	Fill_jump_speed	Fill_scan_delay	Fill_jump_delay	Slicer_fill_first
1	8812632	60	600	1

Outline_scan_on	Outline_scan_delay	Outline_jump_delay	Outline_laser_off
1012	60	500	1363

Beam_offset_enable	Beam_offset_x_radius	Beam_offset_y_radius	Slicer_winding_fill
0	0.1016mm	0.1016mm	1

Figure 9 Report of sintering parameters

CONCLUSIONS

A relational database has been developed for management of the selective laser sintering process. Use of the database makes it is easy to store and retrieve processing information and make decisions for planning the use of SLS equipment. In addition, the database provides an interface to integrate the SLS process with other manufacturing techniques to form part of a CAPP or CIM system. Indeed, this system is aimed at providing a means for effective technology management.

Further research works should be carried out on extending the database to cover all RP processes, incorporating a knowledge base to form an RP planning system. Although using similar data, organized in a similar way, the data interrogation of such a system and the reports would be quite different.

Data collection is important for supporting the database. Further experimental work is ongoing to collect data on materials and prototypes as part of a 'fine-tuning' process. This could also be done with the assistance of other researchers, users and vendors to support this project by providing data concerning their experience in use of the technology.

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