International Journal of Advanced Engineering and Technology
ISSN: 2456-7655
www.newengineeringjournal.com
Volume 1; Issue 1; March 2017; Page No. 32-37

Intelligent knowledge based system for material processing by electron beam machining (EBM) process

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Abstract
Electron Beam Machining (EBM) is a thermal process. This process is a steam of high speed electrons impinges on the work surface so that the kinetic energy of electrons is transferred to work producing intense heating. Depending upon the intensity of heating the work piece can melt and vaporize. In this paper, an intelligent knowledge based system (IKBS) is developed for manufacturability evaluation of electron beam machining (EBM) Process in computer based concurrent engineering environment. The system evaluates manufacturability and estimating machining cycle time and cost. The intelligent system gives valuable information to help designers and manufacturing engineers to improve design and process plan and production of the company. The intelligent system (IKBS) links with design feature library. The design specification is acquired through a feature based approach. The IKBS links with material database which holds attributes of more than 10 type of materials. It also link with EBM database which hold attributes of 3 types of EBM machine, and EBM process database which hold EBM machine parameters. For each design feature, IKBS provides information needed for manufacturability evaluation and estimation of machining cycle time and cost. The IKBS can be used as an advisory system for designers and manufacturing engineers for optimization of design and manufacturing.

Keywords: Electron beam Machining, Intelligent knowledge based system, machining time and cost

1. Introduction

Electron beam machining is a thermal process. This process is used for the metal removal during the machining process. In the electrical beam machining, electrical energy is used to generate the electrons with high energy. In the electron beam gun the electric beam is generated. Electron beam consists of a small spot size, from which it provides the high velocity electrons. The electron beam machining process is carried out in the vacuum. This is due to the electrons present in the process react with the air molecules so they lose the energy and ability of cutting. The work piece material must be placed under the electron beam, and where the equipment is placed under the vacuum [1-4]. With the spot size of 10 to 100, the high energy absorbed electron beam is ready to show impact on the work piece material. The high velocity electron consists of kinetic energy, the energy is converted into the heat energy, where the electrons strikes the work material. Because of the high energy present in the electrons it starts to melting and vaporization of the work piece material. The process is done from top to the bottom of the work piece material. Electron beam is generated in an electron beam gun. Electron beam gun provides high velocity electrons over a very small spot size. EBM uses a focused beam of high-velocity electrons to remove material. In this process, a stream of electrons strikes workpiece and causes rapid melting and vaporization of the material. This process requires a vacuum, so workpiece size is limited to the size of the vacuum chamber. The system consisting of lens and prism is also incorporated. The beam can be controlled very accurately and focused on a width as small as 0.002 mm. The electrons on impingement over the workpiece heat it up and raise its temperature to 5000°C, and the workpiece material melts and vaporizes locally. The source of energy in EBM is high velocity electrons, which strikes the surface of the workpiece and generate heat. Electrons escapes from the hot surface and a voltage of 50 to 200 kV helps to accelerate them. These high energy electrons possess high energy density generally in the order of 10ˆ4 kW/mm². Thin and high energy stream strikes the workpiece. In the electrical beam machining the gun is used in the pulsed mode. By using the single pulse holes, is drilled on the thin sheets. Multiple passes are required for the thicker plates. The process of heating by electron beam is used for annealing, welding or metal removal. During EBM process very high velocities can be obtained by using enough voltage of 150,000 V can produce velocity of 228,478 km/sec and it is focused on 10–200 μM diameter. Power density can go up to 6500 billion W/sq.mm. Such a power density can vaporize any substance immediately. Complex contours can be easily machined by maneuvering the electron beam using magnetic deflection coils. To avoid a collision of the accelerating electrons with the air molecules, the process has to be conducted in vacuum. So EBM is not suitable for large work pieces. Process is accomplished with vacuum. No effects on work piece because about 25-50μm away from machining spot remains at room temperature and so no effects of high temperature on work. EBM process is a steam of high speed electrons impinges on the work surface so that the kinetic energy of electrons is transferred to work producing intense heating. Depending upon the intensity of heating the work piece can melt and vaporize [5-9]. The electron beam machine consists of the following elements: 1) electron beam gun: an electron beam gun used to produce free electrons at the cathode. The high velocity particles are moving through the small spot size. The cathode (tool) is made of tantalum or tungsten material. The cathode filaments are heated to a temperature of 2500to 3000and the heating leads to thermo–ionic emission of electrons. The magnitude varies from the 25 mA to 100 mA. The solidities lies between 5 Ac to 15 Ac. The emission current is influenced by the voltage that is nearly 150kV, and the current is applied between the anode and cathode to release the electrons in the direction of work piece. 2) Bias grid: It is also known as grid cup. The grid cup is a negative that is subjected with respect to the filament. So, the electrons generated with the help of the cathode will directly flow towards the anode. During the flow of the electrodes no diversions are seen. The anode attracts the electrons and gets accelerated; the electrons will gain a high velocity. 3) The cathode controls the flow of the electrons, and the grid cup used to operate the gun in pulsed mode only. 4) After the anode the electron beam passing through the magnetic lens and the apertures are connected in series. The magnetic lens is used to shape the electron beam and reduce the diversion factor. 5) The apertures allow the convergent electrons to permit and caught the low energy divergent electrons from the fringes. 6) Finally the electron beam passes through the electromagnetic lens and deflection coil. Then the deflection coil sends the electron beam through the hole, to improve the shape to machine a hole. 7) The vacuum is created between the work piece and the electron beam gun, and there is a series of rotating disc with slots. 8) The disc allows the electron beam to pass over the material for machining, and it prevents from the fumes and vapors generated during the machining. 9) Work piece is placed on the CNC bench. Then holes of any shape are made on the work piece material. In the gun beam flection and CNC control are used to shape. 10) Vacuum is maintained in gun, and the vacuum ranges from Suitable vacuum are maintained because the electron as it does not lose their energy, and where the life of the cathode is obtained. By using the diffusion pump and rotary pump the vacuum is maintained. 11) Diffusion pump should act as an oil heater. If the oil is heated then the oil vapor rushes upwards. The nozzle changes the direction of the oil vapor and starts moving in the downward direction at high velocity. The oil vapors are reduces in the diffusion pump; this is because of the presence of the cooling water cover. Finally the molten workpiece material, if any at the top of the front, is expelled from the cutting zone by the high vapor pressure at the lower part. Unlike in electron beam machining, the gun in EBM is used in pulsed mode. Holes can be drilled in thin sheets using a single pulse. For thicker plates, multiple pulses would be required. Electron beam can also be maneuvered using the electromagnetic deflection coils for drilling holes of any shape. Schematic illustration of the electron-beam machining process is demonstrated in figure 1. In figure 2 EBM system components is demonstrated.

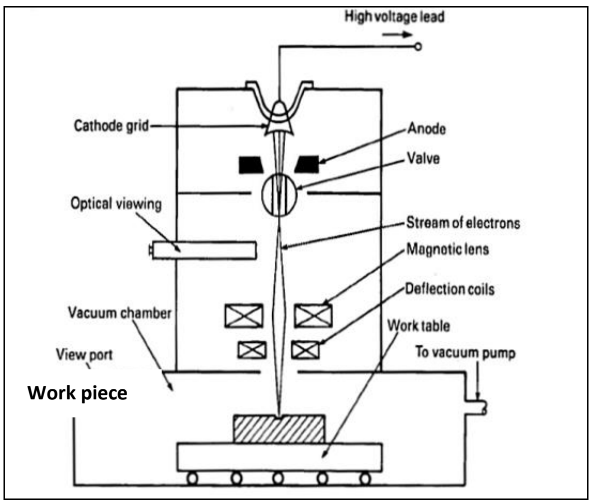

Fig 1: Electron beam machining (EBM) Process

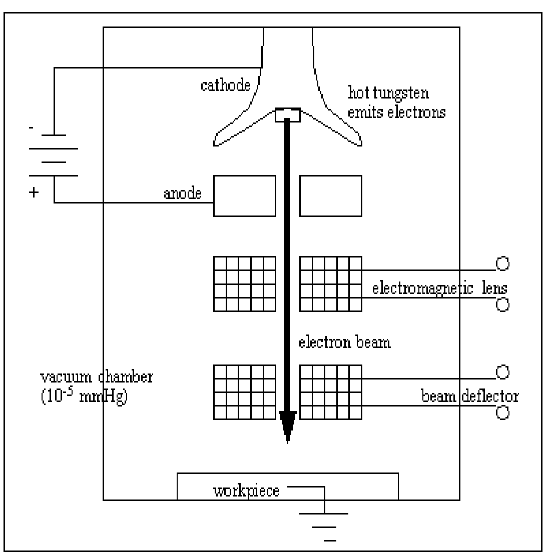

Fig 2: EBM system components

It is also known as grid cup. The grid cup is a negative that is subjected with respect to the filament. So, the electrons generated with the help of the cathode will directly flow towards the anode. The cathode as can be seen in figure 2 is generally made of tungsten or tantalum. Such cathode filaments are heated, often inductively, to a temperature of around 2500 0 C. Such heating leads to thermo-ionic emission of electrons, which is further enhanced by maintaining very low vacuum within the chamber of the electron beam gun. Moreover, this cathode cartridge is highly negatively biased so that the thermo-ionic electrons are strongly repelled away from the cathode. This cathode is often in the form of a cartridge so that it can be changed very quickly to reduce down time in case of failure. During the flow of the electrodes no diversions are seen. The anode attracts the electrons and gets accelerated; the electrons will gain a high velocity. The cathode controls the flow of the electrons, and the grid cup used to operate the gun in pulsed mode only. After the anode the electron beam passing through the magnetic lens and the apertures are connected in series. The magnetic lens is used to shape the electron beam and reduce the diversion factor. The apertures allow the convergent electrons to permit and caught the low energy divergent electrons from the fringes. In figure 3. Mechanism of material removal in electron beam machining is demonstrated. The basic functions of any electron beam gun are to generate free electrons at the cathode, accelerate them to a sufficiently high velocity and to focus them over a small spot size. Further, the beam needs to be maneuvered if required by the gun.

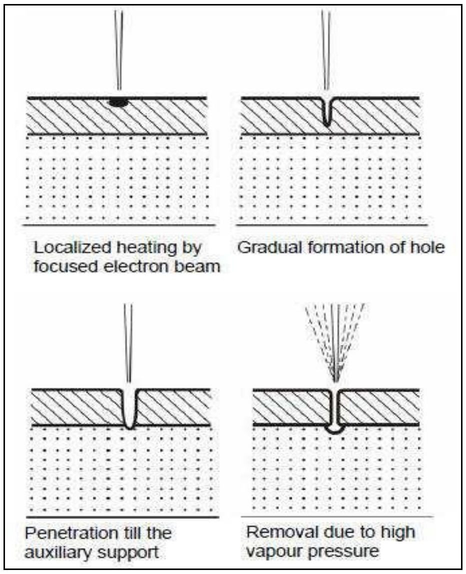

Fig 3: Mechanism of material removal in electron beam machining

2. Parameters in the electron beam machining

The following parameters effects on electron beam machining: 1) Electron beam machining works within the pulse mode. The bias grid is located after the cathode. Then pulse is given to the grid cup, where the pulse duration ranges from 50 to 15 ms. 2) Beam current is related to the electrons that are emitted from the cathode or available in the beam. Beam current is ranges from the 200 micro amps to 1 amp. If the beam current increases, simultaneously there is also an increase in the energy per pulse. High pulse energy is used to machine thicker plates and make the holes larger. 3) The power and energy density is ruled by the energy per pulse and the nozzle spot size. With the help of the electromagnetic lens the spot size is controlled. For lower spot size they require a high energy density. The metal removal must be high; this is when compared to the holes size where the hole must be similar. 4) The plane of focusing must be above or below the surface of the work piece material.

3. Capability, Advantage and application of electron beam [10-13]

Electron bean has many capability such as the following:1) The EBM does not apply any cutting forces on the material: 2) During the process very simple investment is required for work. 3) EBM process allows machining of brittle and fragile materials: 4) Reverse tapper can also be performed below the surface of the work piece. 5) In the electron discharge machining Cut formation is not observed: 6) With the help of the electron discharge machining we can machine the wide range of materials like stainless steel, aluminum, steel, plastics, ceramics etc. 7) Electrical beam machining makes a hole ranges from 100 to 2 mm: 8) The depth of cut must be 15 mm with a length to diameter ratio nearly 10: 9) Holes can be elongated along with the barrel shape or depth: 10) In EBM the heat affected zone is narrow; this is because of the short pulse occurrence. The heat affected zone is nearly 20 to 30. 11) Compares to the steels aluminum and titanium is freely machined: 12) Based upon the type of the material, power density, depth of cut holes diameter, which are the reasons for the number of holes drilled per second on the material.

Electron bean has many advantages such as the following

- No physical or metallurgical damage results in the workpiece.
- Very hard, heat resistant materials could be machined or welded easily
- Close dimensional tolerance could be achieved since there is no cutting tool wear.
- In electron beam welding there is virtually no contamination and close control of penetration is possible.
- Holes as small as 0.002 mm diameter could be drilled.

Electron bean has many application such as the following

- Electron beam can be suitably used for welding small pieces of highly reactive and refractory metals
- It is used for drilling synthetic jewels in the watch industry.
- Holes as small as 0.002 mm diameter can be produced in hard synthetic sapphires.
- Fine copper wire can be welded to in transistors.
- For making fine gas orifices in space nuclear reactors and turbine blades for supersonic aero engines
- Wire drawing dies, flow orifices could be produced by this process.
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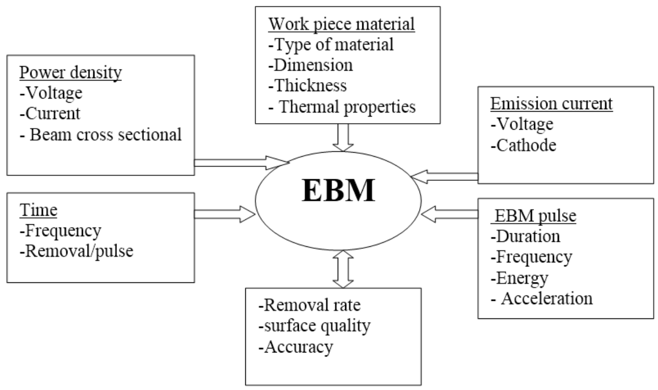

Fig 4: Factors effect on EBM performance

4. Intelligent knowledge based system (IKBS) for Electron beam machining (EBM)

An Intelligent knowledge based system for Electron beam machining is an interactive intelligent program with an expert-like performance for solving a particular type of problem using knowledge base, inference engine and user interface. In this paper the following step has been used:

4.1. Intelligent knowledge based system for Electron beam machining has been developed in a computer based concurrent engineering environment, the third version of an expert system shell (NEXPERT), based on object-oriented techniques (OOT). A Hewlett Packard (HP) workstation was used in development of the IKBS. A geometric specification of design feature, and material type of the workpiece and its thickness is sent for manufacturability evaluation at the various stages in its design. Within the manufacturability procedure, the machining time and cost of producing part, is estimated. The labour and depreciation cost of EBM for each selected design feature specification, is estimated.

4.2. The material specification are described in terms of its thickness, width and it's melting point etc. The attributes of different material types for EBM, and different type of EBM machine are stored in working memory or data-bases.

4.3. The IKBS can retrieve information from working memory and advise the designer on the appropriate choice of material, for workpiece, and type of machine.

4.4. The IKBS also contains information related to good practice rules for EBM and, EBM process capabilities, and constraints.

4.5. For the present IKBS, knowledge has been gathered from literature and talking with expert and experimental results on EBM.

4.6. For each selected design feature undergoing evaluation for its manufacturability by EBM, the cost of the machine cycle is estimated.

4.7. Machine cycle time is also a key factor, which depends for example on setting-up of EBM loading and unloading of work-piece, inspection of component, and general maintenance.

4.8. Assessment of the manufacturability of a workpiece material, usually from machining cycle time and cost, is established automatically by the IKBS.

4.9. This IKBS can advise on the manufacturing of each work piece material. From this information, the process variables can be selected that best balances between the required quality against efficiency of manufacturing.

5. Architecture of intelligent system for electron beam machining

The IKBS contains expertise gathered from both experiment and general knowledge about EBM that can be provided to designers and manufacturing engineers. A flow chart of IKBS is presented in figure 5 from which the following modules are noted:

5.1. Material (workpiece) library

The material (workpiece) library contains 6 different material types for work-piece which interactively acquired by the IKBD for EBM. Each of which can be produced by EBM machine.

5.2. EBM machine characteristics

Information is contained on two different machine type of EBM machines and their capital cost.

5.3. Machining cycle time and cost module

The knowledge base provides estimates of cycle time and costs for each selected design feature based on the selected material type EBM process.

5.4. Manufacturability

The manufacturability is assessed by consideration of the workpiece specification, the EBM production rate of he machine used. Figure6.input, output, constraint, and features library and databases of IKBSEBM is demonstrated.

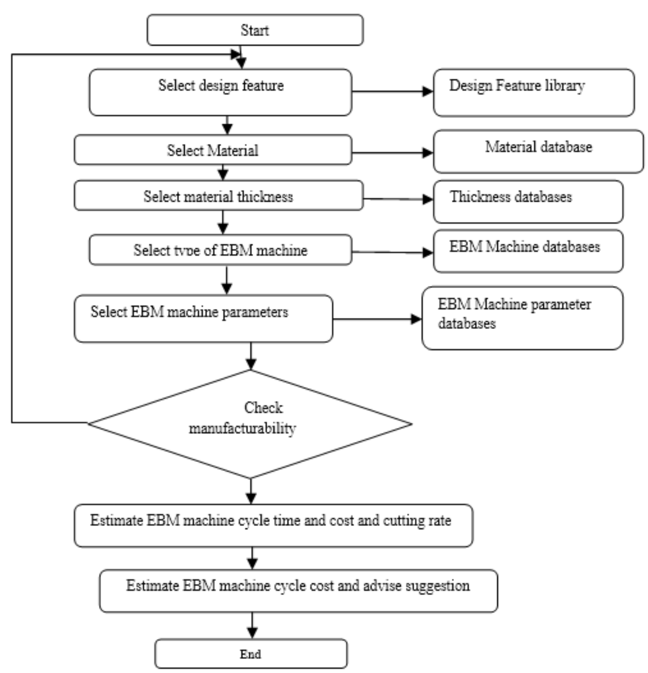

Fig 5: A flow chart of intelligent system for electron beam machining

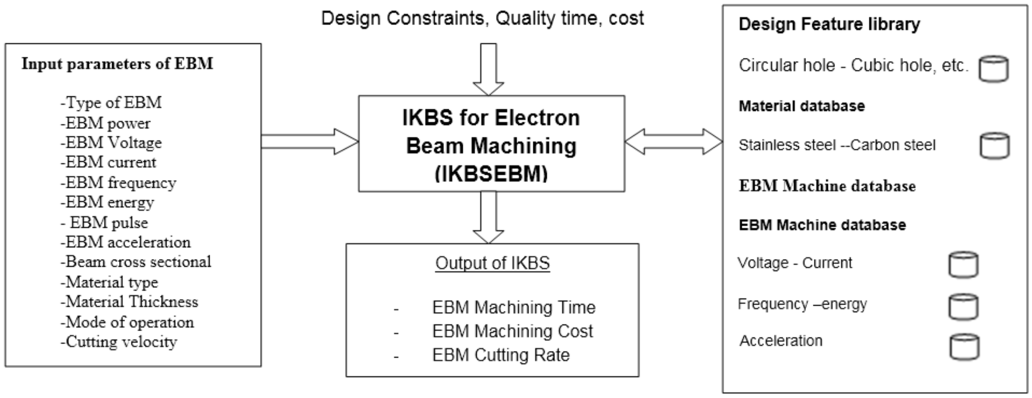

Fig 6: Input, Output, constrains, database of electron beam machining

Table 1: Comparison of experimental EBM marching and IKBS for slot making

Feature slot width length mm	Material type	Workpiece thickness mm	Procedure	EBM current micro A	Accelerating voltage KV	Cutting speed mm/min	EBM machining time (sec)	EBM Machining cost US $
0.1 10	Stainless steel	0.175	Experimental slot cutting	50	130	50	0.2	0.40
0.025 10	Tungsten	0.05	Experimental slot cutting	30	150	124	0.08	0.4
0.1 10	Alumina	0.25	Experimental slot cutting	50	130	50	0.2	50
0.1 10	Brass	0.75	Experimental slot cutting	200	150	600	0.015	600
0.1 10	Stainless steel	0.175	IKBS EBM slot cutting	50	130	50	0.18	50
0.025 10	Tungsten	0.05	IKBS EBM slot cutting	30	150	124	0.073	125
0.1 10	Alumina	0.25	IKBS EBM slot cutting	50	130	50	0.18	50
0.1 10	Brass	0.75	IKBS EBM slot cutting	200	150	600	0.014	600

Table 2: Comparison of experimental EBM marching and IKBS for hole making

Hole diameter mm	Material type	Workpiece thickness mm	Procedure	EBM current micro A	Accelerating voltage KV	Cutting speed mm/min	EBM drilling time (sec)	EBM drilling cost US $
0.125 mm	Stainless steel	2.5	Experimental	50	140	100	10	0.29
0.025mm	Tungsten	0.25	Experimental	30	140	50	0.9	0.03
0.3	Alumina (Al_2O_3)	0.75	Experimental	50	125	60	0.14	0.004
0.025mm	Quartz	3.0	Experimental	200	140	10	0.9	0.025
0.125 mm	Stainless steel	2.5	IKBS EBM hole cutting	50	140	110	9.1	0.266
0.025mm	Tungsten	0.25	IKBS EBM hole cutting	30	140	55	0.8	0.029
0.3	Alumina (Al_2O_3)	0.75	IKBS EBM hole cutting	50	125	66	0.128	0.037
0.025mm	Quartz	3.0	IKBS EBM hole cutting	200	140	11	0.8	0.022

6. Conclusions

Electron beam machining is a thermal process. This process is used for the metal removal during the machining process. In the electrical beam machining, electrical energy is used to generate the electrons with high energy. In the electron beam gun the electric beam is generated. Electron beam consists of a small spot size, from which it provides the high velocity electrons. In this paper, an intelligent knowledge based system (IKBS) was developed for manufacturability evaluation of electron beam machining (EBM) Process in computer based concurrent engineering environment. The system was able to evaluate manufacturability and estimating machining cycle time and cost. The intelligent system gives valuable information to help designers and manufacturing engineers to improve design and process plan and production of the company. The intelligent system links with design feature library. The design specification is acquired through a feature based approach. The IKBS links with material database which holds attributes of more than 10 type of materials. It also link with EBM database which hold attributes of 3 types of EBM machine, and EBM process database which hold EBM machine parameters. For each design feature, IKBS provides information needed for manufacturability evaluation and estimation of machining cycle time and cost. The IKBS can be used as an advisory system for designers and manufacturing engineers for optimization of design and manufacturing.

7. References

1. McGeough JA. Advanced Methods of Machining, Chapman and Hall, London. 1988.
2. Kannatey-Asibu Jr. E. Thermal Aspects of the Split-Beam Electron Machining Concept. ASME Journal of Enginering Materials and Technology. 1991; 113(4):215-221.
3. Kannatey-Asibu Jr. E. Split-Beam Electron Machining. Recent Trends in Machining Science and Technology. 1989, 443-451.
4. Kannatey-Asibu E. Jr, Thermal Aspects of the Split-Beam Electron Machining Concept. ASME Journal of Enginering Materials and Technology. 1991; 113(4):215-221.
5. Chryssolouris G, Anifantis N, Karagiannis S. Electron Assisted Machining: an Overview. ASME Journal of Manufacturing Science and Engineering. 1997; 119:766-769.
6. Chryssolouris G. Electron Machining: Theory and Practice. Springer-Verlag, New York, 1991.
7. Crawford C. Introduction to Electron Beam Technology, John Wiley & Sons, New York, 1962.
8. Gorchakova NG, Kuznetsov LI, Yarygin VN. Electron-Beam Diagnostics of High Temperature Rarefied Gas Flows, Proc. 13 Symposium on Rarefied Gas Dynamics. 1985; 2:825-832.
9. Grote K, Antonsson E. Handbook of Mechanical Engineering, 10th edn, Pringer, Berlin, 2009.
10. Moarrefzadeh A. Finite-Element Simulation of Electron Beam Machining (EBM) Process’, International Journal of Multidisciplinary Sciences and Engineering. 2012; 2(6):51-56,
11. Taminger KMB, Hafley RA. Electron Beam Freeform Fabrication: A Rapid Metal Deposition Process, Proceedings of the 3rd Annual Automotive Composites Conference, 2003.
12. Electron Beams: Useful for More than Just Microscopes, European Tool and Mouldmaking, 2002.
13. Taminger KMB, Hafley RA. Characterization of 2219 Aluminium Produced by Electron Beam Freeform Fabrication, Proceedings of 13th SFF Symposium. 2002, 482-489.