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A review to optimizing the drilling parameter for PMMA

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Abstract: *PMMA (Polymethyl methacrylate) stands out from other plastics due to its high light transmission, It has extremely long service life, its specific properties such as high resistance to UV light and weathering and unlimited coloring options. Added to this, PMMA shows the greatest surface hardness of all thermoplastics. It can be fabricated by means of all thermoforming methods, and therefore offers huge creative scope. Another major benefit is that PMMA is 100% recyclable, which makes an essential contribution to saving natural resources. Drilling and milling operation is the highly recommended machining process for machining the material. Study of this study is on drilling operation. Due to it's highly use in research industries, marine, delicate interior and aerospace material, it parameter optimization is needed for drilling operation.*

Keywords: *PMMA, Delamination, cutting speed, Acrylic, Taguchi method*

I. INTRODUCTION

Composite materials are used in industrial fields, such as aerospace, aircraft, automobile and sports, owing to their advantages in mechanical properties. However, it is difficult to machine composite materials with high efficiency to yield good-quality products. Conventional drilling with twist drill still remains one of the most economical and efficient machining processes for hole making as well as for riveting and fastening structural assemblies in the aerospace and automotive industries. During the past four decades, researches have developed many types of drills, including multifacet drill, saw drill, candlestick still, core drill, step drill and trepanning drill, all aimed at making better holes. With increasing demand for advanced composite materials, not only new concepts of tooling but also different realms of cutting conditions are needed. The step-core drill was developed for the same reason. Delamination is the most common defect during drilling due to the heterogeneity of both fibers and matrix. A few studies have proved that delamination is related to the thrust force in drilling composite material. The contribution of chisel edge to the thrust force for twist drill is often up to 40–60% of the total thrust force. The shorter the chisel edge, the smaller the thrust force will be. Pre-drilled, back-up plates and special drills can reduce delamination when drilling composite materials. Armarego and Wright found that the effects of feed rates, spindle speeds and the geometrical characteristics of the three drills on the resulting torque and thrust values are comparable regardless of the three different drill flank configurations used. Most of the published and manufacturers' literature correlates the drill material, drill geometry and feed rate to the delamination produced by twist drilL. Hocheng and Tsao compared theoretical predictions of critical thrust force with experiment results at the onset of delamination for various drills, such as saw drill, candlestick drill, core drill and step drill. They found that among various drills, core drill allows for the largest drilling feed rate to avoid delamination. In general, the core drill is applied for drilling hard brittle materials, as in civil engineering structure, jewels and glass. However, the removal of chips poses problems when using the core drill. To resolve this, the step-core drill is designed to reduce chip removal in drilling. Although significant efforts have been devoted to understanding the drilling-induced delamination of twist drill, there have been few papers reporting the effect of step-core drill in drilling composite materials. Hence, this study aims to examine experimentally the drilling-induced thrust force of composite materials when using step-core drill.

For the study of parameters affected on the drilling of PMMA and drilling operation following research work has been reviewed:

Irfan Khan et al. working on "Selection of optimum Drilling Parameter in Drilling of commercial Acrylic sheet to achieve minimum Hole Expansion by using Taguchi Approach". They observed that accuracy of the hole depends upon the various factors such as cutting speed, feed, tool geometry, work material and thickness of the work piece to be drilled. During the drilling operation heat is generated at tool work interface, which tends to decrease the accuracy of the hole. They use Taguchi method to achieve the minimum hole size expansion in drilling of **acrylic sheet**. They measure effect of cutting parameters, such as cutting speed and feed rate, and point angle on hole size(without considering the thermal effect). A plan of experiments, based on L9 Taguchi design method was made and drilling was done with the selected cutting parameters. All tests were run at cutting speeds of 660, 1115 and 1750 r.p.m. and feed 0.04, 0.08, and 0.15 mm/rev and point angle of 90°, 118°, and 140°. The optimum level for spindle speed, feed rate and tool angle are observed at v =1750 rpm, f =0.15, θ =118°.

spindle speed(in rpm)	feed rate (in mm/rev)	tool angle(in degree)
660	0.04	90
660	0.08	118
660	0.15	140
1115	0.04	118
1115	0.08	140
1115	0.15	90
1750	0.04	140
1750	0.08	90

Figure 1 Experimental Setup of Drilling Machine & orthogonal Array

Rana M. Taha et al. worked on "hole drilling in polymethyl methacrylate (**PMMA**) using co2 laser". The hole depth, width and penetration velocity of evaporation depend on different constraints such as power, material, exposure time, distance between drilling tool and the material, the drilling tool, etc. They used laser beam as drilling tool. 16W CO_2 laser (10.6μm) and transparent Perspex (PMMA) work piece with 8mm thickness were used. The distance between laser beam and the material was 5cm. Different powers for CO_2 laser were used for different exposure time. The most suitable power for drilling a hole in a PMMA workpiece with 8mm thickness using a CO_2 laser working in CW mode was 2W, where in this value of power, a maximum value of the aspect ratio was achieved by them in this study.

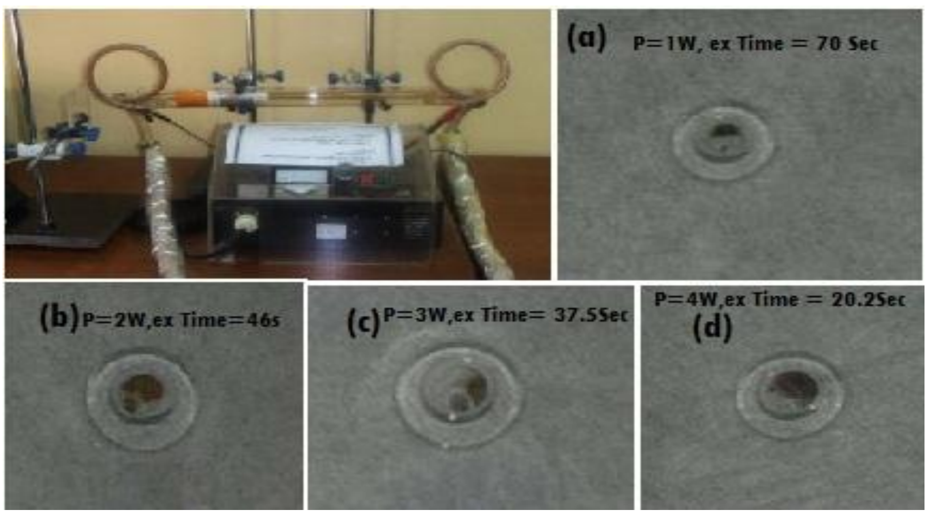

Figure 2 Experimental Setup & Results

Rupeshkumar pandey et al. worked on "Modelling and optimization of temperature in orthopaedic drilling: An in vitro study". They use the Taguchi and response surface methodology (RSM) for modelling and optimization of the temperature produced during bone drilling. The drilling of bone is a common procedure in orthopaedic surgery to produce hole for screw insertion to fixate the fracture devices and implants. They found major problem which encountered during such a procedure is the increase in temperature of the bone due to the plastic deformation of chips and the friction between the bone and the drill. The increase in temperature can result in thermal osteonecrosis which may delay medicinal or reduce the stability and strength of the fixation. They conducted drilling experiments on poly-methyl-meth-acrylate (PMMA) (as a substitute for bone) using Taguchi's L27 experimental design technique. The cutting parameters used are drill diameter, feed rate and cutting speed. They established a second-order model between the drilling parameters and temperature using RSM. The experimental results show that the drill diameter is the most significant drilling parameter affecting the temperature during drilling followed by cutting speed and feed, respectively. The values predicted and the values obtained from experiment are fairly close, which indicates that the developed RSM model can be effectively used to predict the temperature in orthopaedic drilling. Optimal cutting condition for minimum temperature is drill of diameter 6 mm, feed rate of 35 mm/min and spindle speed of 1500 rpm.

	Control factor	Level 1	Level 2	Level 3
A	Drill diameter (mm)	6	8	10
B	Feed rate (mm/min)	35	40	45
C	Spindle speed (rpm)	1500	2000	2500

Figure 3 Factors and levels using in the experiment

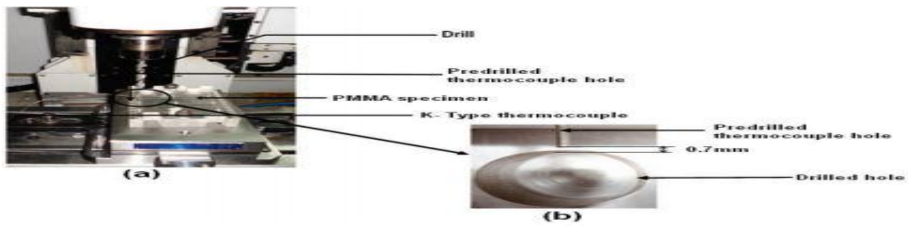

Figure 4 Experimental Setup and enlarged view of the predicted thermocouple hole and drilled hole

Rupeshkumar Pandey et al. worked on "Predicting Temperature in Orthopaedic Drilling using Back Propagation Neural Network". This work deals with the prediction of temperature in orthopaedic drilling using back propagation neural network. Drilling of bone is common to prepare an implant site during orthopaedic surgery. The increase in temperature during such a procedure increases the chances of thermal invasion of bone which can cause thermal osteonecrosis. Drilling operations have been performed in PMMA (as a substitute for bone) work-piece by high- speed steel (HSS) drill bits over a wide range of cutting conditions. Drill diameter, feed rate and spindle speed are used as input for the back propagation neural network whereas temperature is taken as output. The performance of the trained neural network has been tested with the experimental results. Good agreement is observed between the predictive model values and experimental values. Network with 5 neurons in the hidden layer is found to be optimal. Increasing the neurons beyond it increases the complexity of the system as indicated with increase in MSE.

M.M. Hanon et al. Worked on "Comparison between Practical and Theoretical Investigations of Laser Drilling". This paper presents a comparison between the behavior of two different laser drilling processes, The first is a practical drilling application of the alumina ceramic with thickness of 2.2 mm using Nd:YAG laser, whereas the other is a simulation of the transient heat transfer using COMSOL Multiphysics 3.5a for drilling PMMA substrate of thicknesses of 2.5 mm. For Experimental work, Effects of the laser peak power, pulse duration and repetition rate, have been determined using optical images taken from the inlet and outlet of the samples. Different laser beam parameters have been used for the laser drilling process of alumina ceramic. Concerning the simulation, the beam parameters used for this study are selected to simulate drilling process. Effects of laser output power and exposure time have been carried out via the studying of the temperature distribution on the cross section of the substrate to determine the optimum conditions obtained from the combination of parameters that improves hole quality. It has been indicated that the results behaviour of the practical and simulation of this work are in good agreement when compared to each other. Concerning to the simulation, craters have remained a blind hole when the laser output power and the exposure time used 0.96 W and 2 s respectively, while full holes have been investigated when the laser beam reached up to 1.82 W output power and 3 s exposure time.

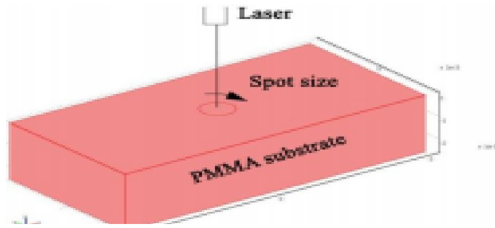

Figure 5 laser beam irradiates a PMMA substrate

Rupesh Kumar Pandey & S.S.Panda at al. Worked on "Optimization of Orthopaedic Drilling: A Taguchi Approach". It is important to minimize the thermal invasion of bone during drilling. They applied Taguchi method to investigate the optimal combination of drill diameter, feed rate and spindle speed in dry drilling of PMMA for minimizing the temperature produced. They found that the diameter has the highest influence on temperature produced during drilling PMMA, followed by the spindle speed and feed rate respectively. The optimal combination of the control factors is A1B2C1 for minimum temperature generation, i.e. drill of diameter 6 mm, feed rate of 35 mm/min and spindle speed of 1500 rpm.

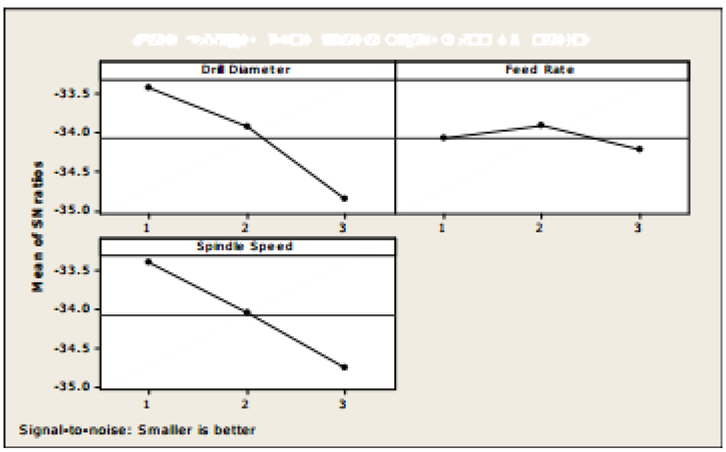

Figure 6 Experimental Setup

Irfan Khan el al. Worked on "Optimization of burr height in drilling of commercial Acrylic sheet using Taguchi method." They worked to investigate the influence of cutting parameters, such as cutting speed and feed rate, and point angle on burr height produced when drilling acrylic sheet by Taguchi experiment. A plan of experiments, based on L9 Taguchi design method, was made and drilling was done with the selected cutting parameters. All tests were run at cutting speeds of 660, 1115 and 1750 r.p.m. and feed 0.04, 0.08, and 0.15 mm/rev and point angle of 90°, 118°, and 140°. The orthogonal array, signal-to-noise ratio, and analysis of variance (ANOVA) were employed to investigate the optimal drilling parameters. It was found that higher cutting speeds and higher feed rate produces better results with higher tool angle 140˚.

Sr.no	v(in rpm)	f (in mm/rev)	Θ (in degree)	H (mm)	S/N for Burr Height
1	660	0.04	90	0.28	-11.0568394
2	660	0.08	118	0.245	-12.2166783
3	660	0.15	140	0.11	-19.1721463
4	1115	0.04	118	0.225	-12.9563496
5	1115	0.08	140	0.09	-20.9151498
6	1115	0.15	90	0.055	-25.1927462
7	1750	0.04	140	0.045	-26.9357497
8	1750	0.08	90	0.03	-30.4575749

Figure 7 Showing average value and S/N ratio for burr height and hole size expansion

Dilip Kumar Bagal at al. Worked on "Experimental Investigation and Modelling Microdrilling Operation of Aerospace Material". They taken 5mm thicker PMMA sheet into account as a work-piece, having length of 80 mm and breadth of 50 mm. The standard diameter of this type of drill-bit is 1mm and the point angle and flute length are 118° and 23 mm respectively. The output parameter of torque and thrust force was measured by the arrangement of 9272A type Kistler Co. prepared quartz 4 component dynamometer and 5070A type multi-channeled charge amplifier. The local circularity error and time are measured by means of JEOL SEM-6480LV machine and stop watch respectively. They found optimal conditions of two process parameters are 20mm/min of feed rate and 2500 RPM of spindle speed. The increased improvement value of S/N ratio is 1.28401 by 57.76% at optimal condition and for reduced improvement value of mean is 0.0947 by 12.23%.

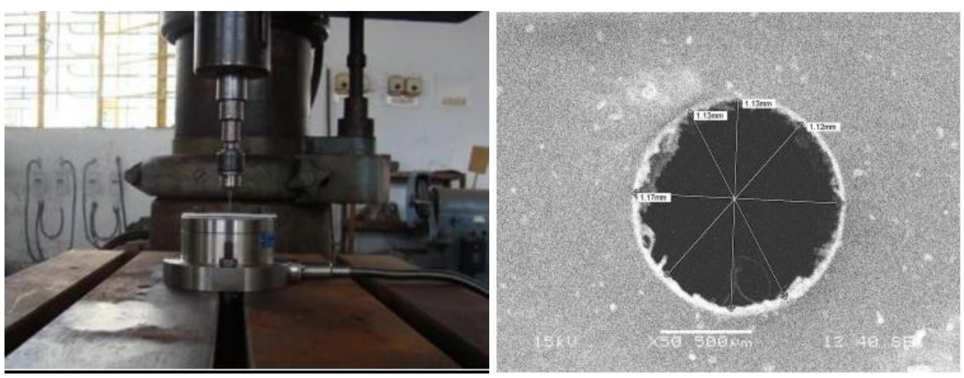

Figure 8 Experimental set up & Micro hole at 25 mm/rev and 2500 rpm

Mohamed I. Hassan at al. Worked on "Scaling Human Bone Properties with PMMA to Optimize Drilling Conditions during Dental Implant Surgery". Dental implant surgery is an effective alternative for replacement of missing teeth. The success of the implant depends on how well the bone heals around the implant. However, the excessive heat generated during drilling may create a necrotic zone in the drilled area, which prevents the growth of bone around the implant. Using human bone for the many experiments needed to investigate factors that affect heat generation during drilling, it is impracticable to obtain human bone so they substitute a material used as bone cement. They reports results obtained by drilling PMMA under different conditions and discusses how these results are scaled to represent human bone. PMMA specimens of 5 cm diameter and 2 cm thickness are prepared. Each specimen has two type K thermocouples inserted at 6 cm apart and at 6 cm to the drilling centreline as shown in figure 2.9. The drilling, using a HAAS machine, was carried out at three different cutting speeds (1200, 1800 and 2200 rpm), three different depths (8, 12 and 16 mm) and with three different drill diameters (2, 3.5 and 4.3 mm) with a constant feed rate of 0.42 mm/s. They observed that the maximum temperature increases with an increase of drill diameter, the maximum PMMA temperature increases with an increase of drilling depth, and the maximum PMMA temperature almost linearly increased with an increase of the drilling speed.

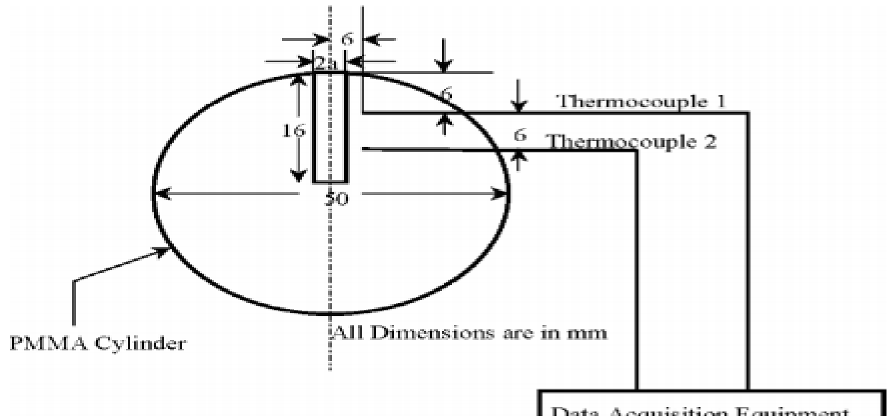

Figure 9 Schematic diagram of Experimental setup

Bismay kumar behera el al. worked on "parametric optimization of microdrilling in aerospace material". They worked to minimize the thrust forces, Circularity Error and Burr size reduction in the micro drilling process on a PMMA (Poly methyl methacrylate) strip of 95*30*4mm by application of the DOE method integrated with Grey Relational Analysis. Taking into account the drilling thrust, Circularity and burr size, 2 machining Controllable parameters such as federate, spindle speed, are optimized based on the DOE method. A Run order was developed by taking the two factors each having 3 levels using Statistical package. Based on the sequence, drilling was done by taking HSS drill bit of size 1mm dia. A Run order was developed by taking the two factors each having 3 levels using Statistical package. Based on the sequence, drilling was done by taking HSS drill bit of size 1mm dia. They found that high speed and low feed is giving a better result having low circularity error and small burr size.

Figure 10 Experimental Setup

D. Chandramohan et al. "drilling of natural fiber particle reinforced polymer composite material". An effort to utilize the advantages offered by renewable resources for the development of bio composite materials based on biopolymers and natural fibers has been made through fabrication of Natural fiber powdered material (Sisal (Agave sisalana), Banana (Musa sepientum), and Roselle (Hibiscus sabdariffa)) reinforced polymer composite plate material by using bio epoxy resin. This work focused on the prediction of thrust force and torque of the natural fiber reinforced polymer composite materials, and the values, compared with the Regression model and the Scheme of Delamination factor / zone using machine vision system, also discussed with the help of Scanning Electron Microscope [SEM]. The Electron Dispersive X-Ray Thermo detector [EDX] machine Model was used to study the composition of the microstructure of composites specimens. It can be concluded that the torque slightly increases as the cutting speed increases. The results indicate that the torque increases as the feed increases. At high feed values, the thrust force decreases with an increased cutting speed.

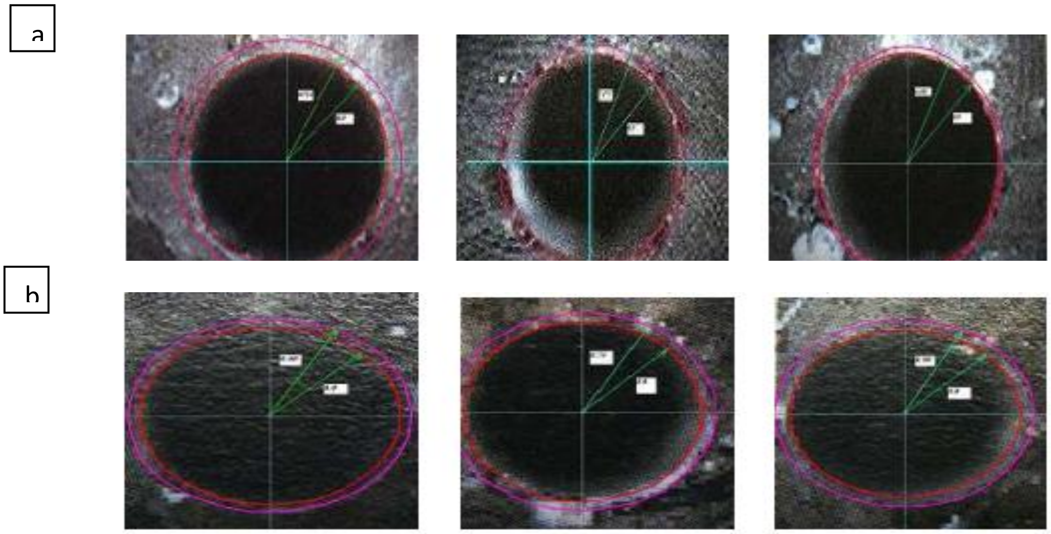

Figure 11(a,b) delamination zone Roselle and Sisal 3,4 & 5 mm dia. Respectively

N.S. Mohan et al. worked on “Influence of process parameters on cutting force and torque during drilling of glass–fiber polyester reinforced composites”. They applied Taguchi optimization methodology to optimize cutting parameters in drilling of glass fiber reinforced composite (GFRC) material. Analysis of variance (ANOVA) is used to study the effect of process parameters on machining process. The measured results has been collected and analyzed with the help of the commercial software package MINITAB14 by them. An orthogonal array, signal-to-noise ratio are employed to analyze the influence of these parameters on cutting force and torque during drilling. The main objective is to find the important factors and combination of factors influence the machining process to achieve low cutting low cutting thrust and torque. From the analysis of the Taguchi method indicates that among the all-significant parameters, speed and drill size are more significant influence on cutting thrust than the specimen thickness and the feed rate. Study of response table indicates that the specimen thickness, and drill size are the significant parameters of torque. They observed using the response table for S/N ratio, for the optimum cutting conditions F3, N4, T1, D1 resulted in the estimated torque of 0.49 N m and from the experiment the value of torque is found to be 0.489 N m, confirming within the 99.79% of confidence

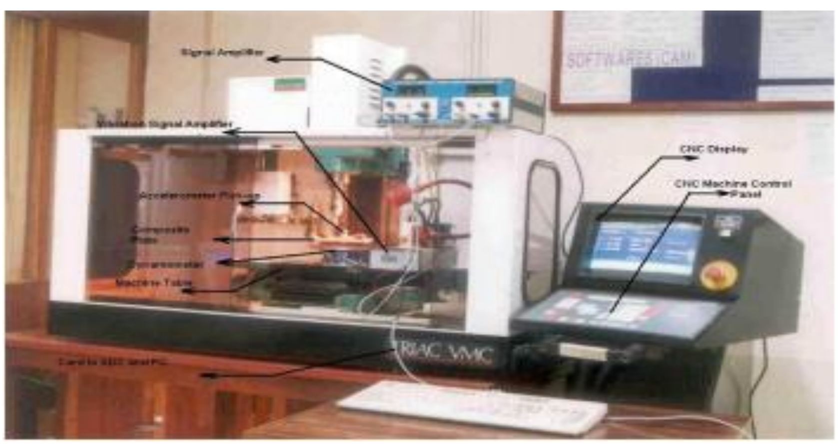

Figure 12 Experimental Setup

Ashish Bharti et al. worked on “Parametric optimization of multi response factors in micro drilling operation”. This paper presents the case study to find the optimized multi response factors for micro drilling operation. The Machining parameters spindle speed ,feed rate and tool point is analyzed for their effect on the hole diameter produced and the material removal rate. Taguchi based method along with ANOVA (Analysis of Variance) and DOE (Design of Experiments) is implemented for optimized result. Drilling operation was done by 1mm (1/64 inch) drill bit with different combination spindle speed, feed rate and tool point angle. Hole produced by drilling is measured using optical imaging microscope and material removal rate is calculated. Signal to Noise Ratio (SNR), Orthogonal Array $L9$ is implemented for experimental layout and data obtained is used as output response in micro drilling Statical Software Minitab 15 is used for calculated the SNR value and result is drawn by ANOVA. Optimum drilling parameters were selected as $N2$ for speed = 2000 rpm, $f3$ feed rate =.13 mm/rev and θ 2 Tool point angle =126°.

Trial no.	Speed N	Feed f	Point θ	S/N ratio
1	1	1	1	-2.69155
2	1	2	2	-2.83001
3	1	3	3	-2.89088
4	2	1	2	-2.77436
5	2	2	3	-2.87923
6	2	3	1	-2.92367
7	3	1	3	-2.81130
8	3	2	1	-2.90474
9	3	3	2	-2.93697

Figure 13 calculation of S/N ratio for Experimental work

I.A.Choudhury et al. worked on "laser cutting polymeric materials: an experimental investigation". Using RSM CCD technique, a predictive model have been developed to analyze the effects of the laser power, cutting speed and compressed air pressure against the HAZ, surface roughness and dimensional accuracy for three different polymer materials (PP, PC, PMMA). The results of the experiment showed that the HAZ is directly proportional to the laser power and inversely proportional to cutting speed and compressed air pressure. It was observed that the **quality of cut of PMMA is much better than PC and PP.** Surface roughness is found to be inversely proportional to all the parameters with cutting speed and compressed air has more influence on it than laser power. The dimensional deviations for all measured dimensions were around 0.07 mm.

Figure 14 Experimental setup and work piece of material PP, PC, PMMA

Yu-Teng Liang et al. Worked on "Investigation into Micro Machining Cutting Parameters of PMMA Polymer Material Using Taguchi's Method". Grey-Taguchi method they used to optimize the micro-drilling of PMMA polymer with multiple performance characteristics. The four parameters being optimized are coating layer, feed rate, spindle speed, and depth of cut. The performance of the drilling process was evaluated by two performance characteristics, namely drill wear and surface roughness. The orthogonal array L9, grey relational analysis, and analysis of variance were used to study the two performance indices. The optimal combination of parameters was determined by using the grey relational grade, a performance index formed by combining the two performance characteristics. The experimental results show that TiAlN coating drills generate least wear and thus possess the longest tool life and the best holes quality.

Figure 15 Experimental setup; Right: A close view of the drill and the workpiece.

Varahalaraju Kalidindi et al. “optimization of drill design and coolant systems during dental implant surgery”. Experiments were carried out to investigate the affect of variable drilling factors on heat generation during drilling operation. Polymethylmethacrylate (PMMA) is the material chosen for this experiment. A theoretical model was developed to study the effect of different drilling parameters on temperature rise during drilling operations. Comparison of observed results obtained from experiments was made with the results from theoretical study. To study the optimum drilling speed experiments are performed for three different speeds of 1200, 1800 and 2200 RPM, three different depths of 8, 12 and 16 mm and three different diameters of 2, 3.5 and 4.3mm; while the feed rate is kept constant at 0.0508 m/sec, hole is being drilled for 16 mm in depth and drill diameter is 2 mm. Comparison of results for PMMA and human bone are also shown explaining how PMMA material can be substituted for human bone.

CONDITIONS	PARAMETERS
Drilling Speed (R.P.M)	1200, 1800, 2200
Drilling Depth (mm)	8, 12, 16
Drill Bit Diameter (mm)	2.00, 3.50, 4.30
Drill Feed Rate (m/sec)	0.00508, 0.01016,0.01524

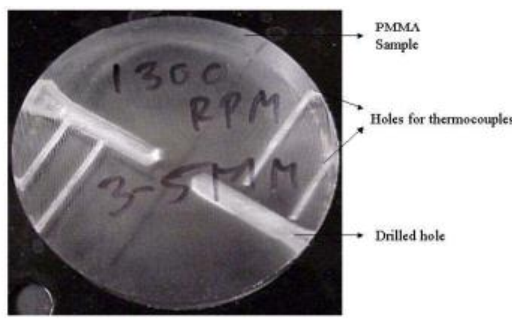

Figure 16 Experimental Parameters and PMMA Specimen drilled at 1300 RPM with 3.5 mm diameter drill

II. CONCLUSION

From the above study it has been observed that PMMA is highly preferred in orthopaedic treatment, dental surgery, in aerospace material and so much more applications are available with high quality parameters required for machining or drilling operation. Most of the researchers are working with Taguchi Method for design of experiment. It has been needed to observe and optimize the effect of parameters on the PMMA drilling and applying the RSM method to optimizing.

REFERENCES

[1.] Khan, Irfan, et al. "Selection of optimum Drilling Parameter in Drilling of commercial Acrylic sheet to achieve minimum Hole Expansion by using Taguchi Approach." *International Journal of Engineering Science and Technology (IJEST), ISSN* (2012): 0975-5462.

[2.] Taha, Rana M. "HOLE DRILLING IN POLYMETHYL METHACRYLATE (PMMA) USING CO2 LASER."

[3.] Pandey, RUPESH KUMAR, and SUDHANSHU SEKHAR Panda. "Modelling and optimization of temperature in orthopaedic drilling: An in vitro study."*Acta of Bioengineering and Biomechanics* 16.1 (2014).

[4.] kumar Pandey, Rupesh, and S. S. Panda. "Predicting Temperature in Orthopaedic Drilling Using Back Propagation Neural Network." *Procedia Engineering* 51 (2013): 676-682.

[5.] Hanon, M. M. "Comparison between Practical and Theoretical Investigations of Laser Drilling." (2014).

[6.] Pandey, Rupesh Kumar, and S. S. Panda. "Optimization of orthopaedic drilling: a Taguchi approach." *Int J Theor Appl Res Mech Eng* 1.1 (2012): 9-12.

[7.] Khan, Irfan, Mukesh Verma, and S. S. Mann. "Optimization of burr height in drilling of commercial Acrylic sheet using Taguchi method." *Optimization* 2.1 (2012): 305-310.

[8.] BAGAL, DILIP KUMAR. *EXPERIMENTAL INVESTIGATION AND MODELLING MICRODRILLING OPERATION OF AEROSPACE MATERIAL*. Diss. NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA, 2012.

[9.] Hassan, Mohamed I., et al. "Scaling Human Bone Properties with PMMA to Optimize Drilling Conditions During Dental Implant Surgery." *Progress in Scale Modeling*. Springer Netherlands, 2008. 497-507.

[10.] Behera, Bismay Kumar (2011) *Parametric optimizartion of microdrilling in aerospace material*. BTech thesis. ID code – 2416.

[11.] Chandramohan, D., and K. Marimuthu. "Drilling of natural fiber particle reinforced polymer composite material." *International Journal of Advanced Engineering Research and Studies* 1.1 (2011): 134-145.

[12.] Mohan, N. S., A. Ramachandra, and S. M. Kulkarni. "Influence of process parameters on cutting force and torque during drilling of glass–fiber polyester reinforced composites." *Composite Structures* 71.3 (2005): 407-413.

[13.] Bharti, Ashish, and S. K. Moulick. "Parametric optimization of multi response factors in micro drilling operation." *Int. J. Sci. Eng. Res* 4.7 (2013): 1157-1163.

[14.] Choudhury, I. A., and S. Shirley. "Laser cutting of polymeric materials: an experimental investigation." *Optics & Laser Technology* 42.3 (2010): 503-508.

[15.] Liang, Yu Teng, and Yih Chih Chiou. "Investigation into Micro Machining Cutting Parameters of PMMA Polymer Material Using Taguchi's Method."*Key Engineering Materials*. Vol. 419. Trans Tech Publications, 2009.

[16.] Kalidindi, Varahalaraju. "Optimization of drill design and coolant systems during dental implant surgery." (2004).