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Modelling and Mass Optimization of CNC Machine Arbor for Maximum Cutting Force by Using Altair Inspire

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ABSTRACT: Traditionally, the design field has been identified with particular end products, e.g., mechanical design, electrical design, ship design. In these fields, design work is largely based on specific techniques to foster certain product characteristics and principles. The scope of this work includes, to design, model and simulate the CNC arbor, to optimize the cutting tool arbor for maximum stiffness condition and also to detailed factor safety in design . When new software and manufacturing processes are introduced, traditional empirical knowledge is unavailable and considerable effort is required to find starting design concepts. Milling operation is today the most effective and productive manufacturing method for roughing and finishing large surfaces of metallic parts. The model simulates precisely the mass optimization of cutting tool and structural analysis to study the optimized model is to make sure that the arbor in safe condition. The accuracy of the simulation model has been thoroughly verified, with the aid of a wide variety of experiments. The analysis of mass optimization and structural analysis is performed in the Altair inspire software.

Key words: Optimization, CNC, Cutting force, Design, Arbor

I. INTRODUCTION

Today, Computer Numerical Control is an extension of what was once Numerical Control. It refers essentially to the concept of controlling automated machine tools via programmable computers. Clearly, with the older system of Numerical Control, a computer wasn't involved, but today the technology has advanced in leaps and bounds (and continues to advance every year). CNC has set the stage for a tremendous upsurge in productivity – it's an environment where machine tools can operate automatically, and without the attention and oversight of an operator.

Historically, the first commercial Numerical Control machines were used in the early 1950's, and operated with "punch tape". And although a proven method, the so-called "new" technology was not readily accepted by manufacturers. In the late 1950's, Numerical Control began to capture the interest of more and more manufacturers, but still with some problems and issues that required attention. Things became more manageable when industry groups standardized the operational aspects of NC, bringing some order and commonality to the manufacturing sector.

Over the years, as CNC technology gained acceptance (with proven results), manufacturers began to replace older technologies and manual machining methods with Computer Numerical Control. And while the United States launched the CNC technology revolution, Germany and Japan became more successful in enhancing the technologies and bringing down unit costs. In more recent years, microprocessors have brought down unit costs even more, and have made CNC technology much more accessible to smaller manufacturing companies, as well as individuals. Whether it's metal cutting machines, or woodworking machines, the technology is being used universally, and with advanced applications emerging every year. As for the CNC machinist, CAD programs, CAM programs, and other computer software are the basis for designing and fabricating almost every product that consumers use on a daily basis. Indeed, like the 1950's and 1960's, advances and innovations in technology will continue to revolutionize throughout the 2000's.

The term "CNC" is a generic term which can be used to describe many types of device, this would include plotters, vinyl cutters, 3D printers, milling machines and others. CNC stands for Computer Numerically Controlled and basically means that the physical movements of the machine are controlled by instructions, such as co-ordinate positions that are generated using acomputer.The term "CNC Machine" is typically used to refer to a device which uses a rotating cutting tool which moves in 3 or more axes (X, Y and Z) to cut-out or carve parts in different types of materials. The information on these pages will focus on what are typically referred to as "CNC Routers" although it would be applicable to most CNC milling and engraving

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II. REVIEW OF LITERATURE

Over the years a lot of research work has been done over the working of a Computer Numeric Control machine and optimization of its process parameters in order to have a controlled and feasible output. Here is some of the research works done under explained as the literature review.

Prajapati, K. have optimized the machining parameters for SR and MRR in CNC turning. SS 316 (austenite steel) work material of Ø 45 mm and length 35 mm was used in turning in dry environment conditions. In this study, the effect and optimization of machining parameters (cutting speed, feed rate and depth of cut) on SR and MRR is investigated. An L27 Orthogonal array, analysis of variance (ANOVA) and grey relation analysis is used. The percentage contribution of cutting speed is 5.29 %, feed of 86.13 % and depth of cut of 3.27 % on surface roughness. From the ANOVA it is conclude that the feed rate is most significant parameter which contributes more to surface roughness. In multi response optimization the optimum parameter combination is meeting at experiment 3 and its parameter value is 1.4 mm depth of cut, 125 m/min cutting speed and 0.1 mm/rev feed rate. From the ANOVA it is conclude that the depth of cut is most significant parameter which contributes more to material removalrate.

Zhang, Julie, Z. investigated the Taguchi design application to optimize surface quality in a CNC face milling operation. An orthogonal array of L9 was used and ANOVA analyses were carried out to identify the significant factors affecting surface roughness. CNC Mill: Fadal VMC-40 vertical machining center was used for this experiment and 19.1×38.1×76.2 mm aluminum blocks as a work piece. The experimental results indicate that in this study the effects of spindle speed and feed rate on surface were larger than depth of cut for milling operation. In this study the optimal cutting condition for face milling was selected by varying cutting parameters through the Taguchi parameter design method. With the L9(34) orthogonal array, a total of 36 experimental runs, covering three main factors each at three levels and two noise factors each at two levels, indicated that the Taguchi parameter design was an efficient way of determining the optimal cutting parameters for surface finish. The experimental results indicate that in this study the effects of spindle speed and feed rate on surface were larger than depth of cut for milling operation. In addition, one of the noise factors, tool wear, was found to be statistically significant. The surface finish achievement of the confirmation runs under the optimal cutting parameters indicated that of the parameter settings used in this study, those identified as optimal through Taguchi parameter design were able to produce the best surface roughness in this milling operation. This was accomplished with a relatively small number of experimental runs, given the number of control and noise factors, suggesting that Taguchi parameter design is an efficient and effective method for optimizing surface roughness in a milling operation.

Joshi, A. investigated the SR response on CNC milling by Taguchi technique. Analysis of variance (ANOVA) was used in this investigation. The material used for the experiment is (100 x 34 x 20 mm) 5 blocks of aluminum cast heat-treatable alloy. The output characteristic, surface finish is analysed by software Minitab 15 and ANOVA is formed, which shows the percentage contribution of each influencing factor on surface roughness. CNC End milling is a unique adaption of the conventional milling process which uses an end mill tool for the machining process. CNC Vertical End Milling Machining is a widely accepted material removal process used to manufacture components with complicated shapes and profiles. During the End milling process, the material is removed by the end mill cutter. The effects of various parameters of end milling process like spindle speed, depth of cut, feed rate have been investigated to reveal their Impact on surface finish using Taguchi Methodology. Experimental plan is performed by a Standard Orthogonal Array. The results of analysis of variance (ANOVA) indicate that the feed Rate is most influencing factor for modeling surface finish. The graph of S-N Ratio indicates the optimal setting of the machining parameter which gives the optimum value of surface finish. The optimal set of process parameters has also been predicted to maximize the surfacefinish.

Reddy, B. Pre-hardened steel (P20) is a widely used material in the production of molds/dies due to less wear resistance and used for large components. In this study, minimization of surface roughness has been investigated by integrating design of experiment method, Response surface methodology (RSM) and genetic algorithm. To achieve the minimum surface roughness optimal conditions are determined. The experiments were conducted using Taguchi's L50 orthogonal array in the design of experiments (DOE) by considering the machining parameters such as Nose radius (R), Cutting speed (V), feed (f), axial depth of cut (d) and radial depth of cut(rd). A predictive response surface model for surface roughness is developed using RSM. The response surface (RS) model is interfaced with the genetic algorithm (GA) to find the optimum machining parameter values. In this study, an efficient optimization methodology using RSM and GA is introduced in minimizing surface roughness of P20 mold steel in CNC end milling process. To achieve the minimum surface roughness, the appropriate process parameters are determined. Nose radius, cutting speed, feed rate, axial depth of cut and radial depth of cut are considered as process parameters. A predictive model for surface roughness is created in terms of the process parameters using RSM to increase the quality of the surface finish. The RSM model is interfaced with an effective GA to find the optimum process parameter values. GA has reduced the

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surface roughness of the initial model significantly. Surface roughness is improved by about44.22%.

Kromanis, A. studied to develop a technique to predict a surface roughness of part to be machined. 3D surface parameters give more precise picture of the surface; therefore it is possible more precisely to evaluate the surface parameters according to technological parameters. In result of the study, the mathematical model of end-milling is achieved and qualitative analysis is maintained. Achieved model could help technologists to understand more completely the process of forming surface roughness. Pre-hardened steel (P20) is a widely used material in the production of molds/dies due to less wear resistance and used for large components. In this study, minimization of surface roughness has been investigated by integrating design of experiment method, Response surface methodology (RSM) and genetic algorithm. To achieve the minimum surface roughness optimal conditions are determined. The experiments were conducted using Taguchi's L50 orthogonal array in the design of experiments (DOE) by considering the machining parameters such as Nose radius (R), Cutting speed (V), feed (f), axial depth of cut (d) and radial depth of cut (rd). A predictive response surface model for surface roughness is developed using RSM. The response surface (RS) model is interfaced with the genetic algorithm (GA) to find the optimum machining parameter values.

Bajic, D. this paper focuses on surface morphology of machined brass reinforced epoxy composite with different particle sizes in computer numerical control (CNC) milling process. Morphological studies in this research contain composite's surface roughness and dispersion of brass particles. Surface roughness is a proper criterion for predicting the performance of machining parameters and the quality of products. In this experiment, cutting parameters evaluated are feed rate, spindle speed, and depth of cut. Scanning electron microscope (SEM) and surface roughness measurement are carried out to study the major changes in texture of the machined surface and determine the optimal mixed-level array of cutting parameters. The results indicate that these parameters have significant effects on surface roughness. In the other word, a better surface quality can be obtained by varying the level of cutting parameters. In addition, it is concluded that a better surface roughness would be achieved by using the smallest size of brass particles.

Inspire Introduction

Altair Engineering Inc. is an American multinational information technology company headquartered in Troy, Michigan. It provides software and cloud solutionsfor simulation, IoT, high performance computing (HPC), data analytics, and artificial intelligence (AI). Altair Engineering is the creator of the HyperWorks CAE software product, among numerous other software packages and suites. The company was founded in 1985 and went public in 2017. It is traded on the Nasdaq stock exchange under the stock ticker symbol ALTR.

Altair Engineering was founded in 1985 by James R. Scapa, George Christ, and Mark Kistner in Troy, Michigan. Since the company's outset, Scapa has served as its CEO (and now chairman). Initially, Altair started as an engineering consulting firm, but soon branched out into product development and computer-aided engineering (CAE) software. In the 1990s, it became known for its software products like HyperWorks, OptiStruct, and HyperMesh, which were often used for product development by the automotive industry. Some of Altair's early clients included the Ford Motor Company, General Motors, and Chrysler. Its software also aided in the development of the *Young America*and *AmericaOne* racing yachts, the former of which was used to compete in the 1995 America's Cup.

Its software also found uses in other sectors, including aerospace (NASA), aviation (Airbus), consumer electronics (Nokia), and toy manufacturing (Mattel), among others. In 2002, Altair software aided in the design of the Airbus A380 by weight optimizing the aircraft wing ribs. That year, the company moved into a new headquarters in Troy, Michigan. It maintained separate offices in Allen Park, Michigan. Also in 2002, Altair opened offices in Seongnam, South Korea and Shanghai, China, adding those locales to its international footprint alongside India where it had begun investment in 1992.

In addition to its software production, Altair continued hiring out engineering consultants to its corporate clientele. Its consultancy services accounted for the majority of the company's revenue until 2004, when the sale and licensing of software overtook that. In October of that year, General Atlantic invested $30 million in Altair. Also in 2004, Altair partnered with General Motors and the United States Department of Défense on the design and construction of a new military vehicle.

III. RESULTS AND DISCUSSION

Mass Optimization Of CNC Arbor

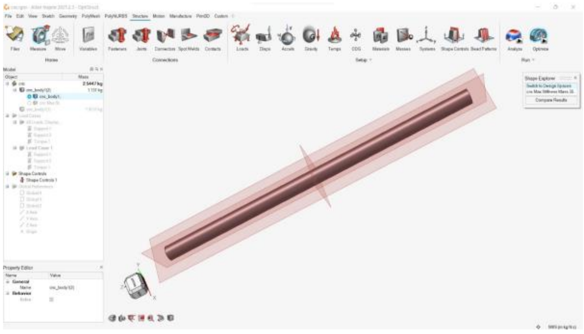

Fig 1 before optimization of arbor

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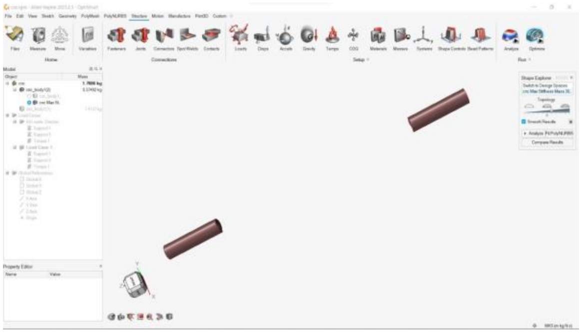

Fig 2 after optimization optimization of arbor

IV. SIMULATION OF CNC ARBOR

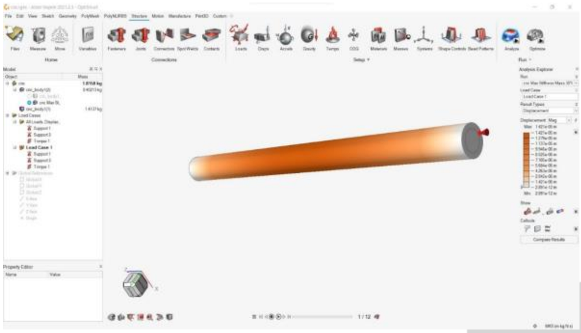

Fig 3 displacement of CNC arbor

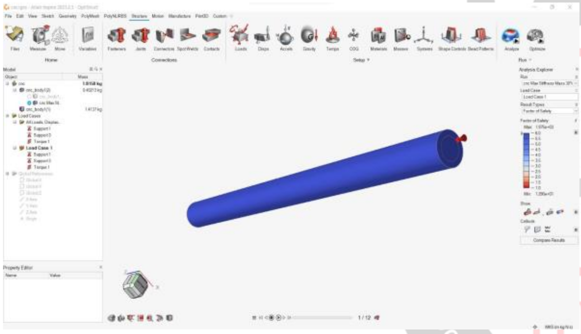

Fig 4 factor of safety of CNC arbor

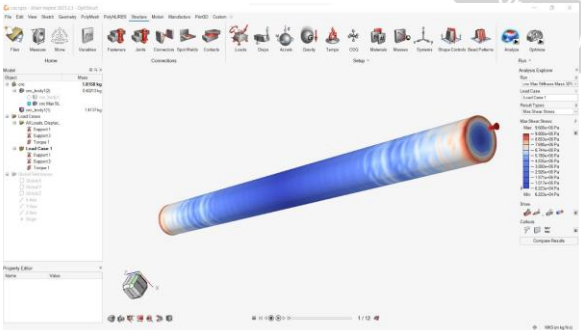

Fig 5 maximum shear stress of CNC arbor

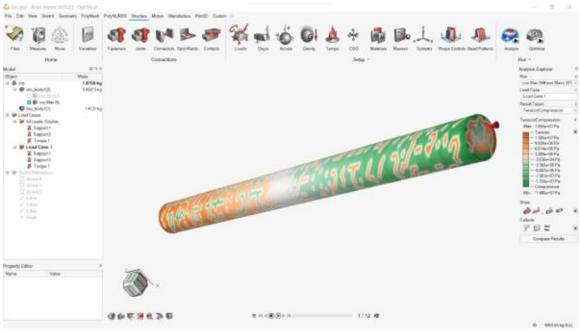

Fig 6 tension/compression in the CNC arbor

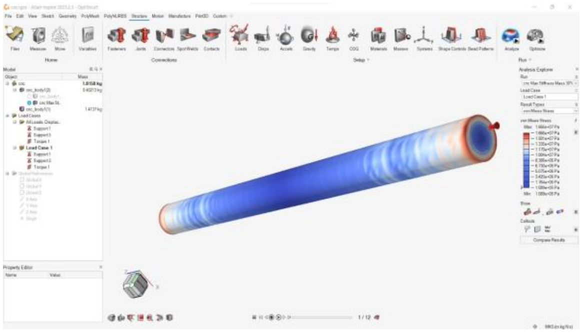

Fig 7 von mises stresses in the CNC arbor

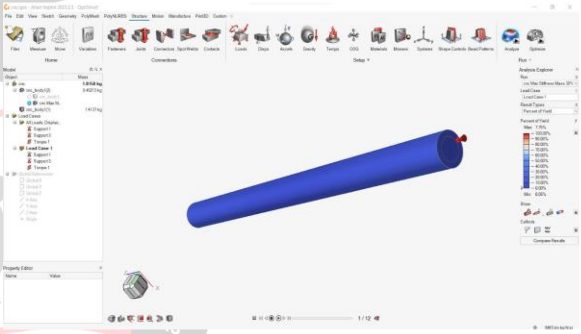

Fig 8 percent of yield in the CNC arbor

	BEFORE OPTIMIZATION		AFTER OPTIMIZATION	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
MASS		2.5447		1.786
DISPLACEMENT	0	2.322e-12m	2.891e-12m	1.421e-05m
FACTOR OF SAFETY	1.398e+07	3.766e+10	1.290e+01	1.975e+03
PERCENTAGE OF YIELDING	0	0	0.05%	7.75%
TENSION/COMPRESSION	-1.538e+3pa	1.408e+01pa	-1.666e+7pa	1.659e+7 pa
MAXIMUM SHEAR STRESS	3.296e-3pa	8.845e+0 pa	6.223e+4pa	9.608e+6 pa
VON MISES STRESS	5.709e-3pa	1.538e+1 pa	1.089e+5pa	1.666e+7 pa

V. CONCLUSION

CNC machines are plays major role in production of mechanical components. CNC milling machines are used to perform multiple operations machine the components. Where the CNC milling arbor is used to hold the cutting tools and take opposite thrust forces.

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Arbor designed in the solid works too to analyse the model for maximum stiffness condition. After performing the analysis, the weight of the of the arbor reduced to 1.786 kg. To make sure that the safety of the CAD model we have performed the structural analysis to study the mechanical behavior of the arbor.

By performing the simulation of CNC milling arbor we found that the arbor in the safe condition with the minimum displacement of 1.421e-05 m. The developed displacement value is very less.

After performing the structural analysis the factor safety of the arbor is within the acceptable range. The percent of yield in the arbor is 7.75% which is very less. By performing the simulation we can say that the optimized model is in the safe condition.

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