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Preface

The 1st International Materials, Industrial, and Manufacturing Conference (MIMEC2013) is held in Johor Bahru, 4 – 6 December 2013. It is grateful that the Proceedings of MIMEC2013 is completed. In accordance to its name, Proceedings of MIMEC2013 is publishing manuscripts within the area of Materials Engineering, Industrial Engineering, and Manufacturing Engineering. Considering the complexity and multidisciplinary nature of engineering problems, manuscripts on related fields or of interdisciplinary nature are also included. The Proceedings of MIMEC2013 is published in two issues, and this book is the first of them. On behalf of the Organizing Committee, I would like to thank the Authors for choosing MIMEC2013 to publish their works and to congratulate them on the publication of their manuscripts in MIMEC2013 Proceedings.

I would also like to express my appreciations to all who have supported the organizing of MIMEC2013. To the core team: Prof. Izman Sudin (General Chair), Prof. Noordin Mshd Yusof (International Scientific and Advisory Board Chair), and Dr. Fethia M. Nor (Organizing Vice Chair). It was due to their support this idea of organizing an international conference can realize. Sincere gratitude is also expressed to International Scientific and Advisory Board members, Session Developers, Organizing Committee members, Keynote Speakers, Invited Speakers, Authors, Reviewers, Participants, Volunteers, Students, and Crew who support and are involved in organizing this international conference. I would also like to extend the appreciation to sponsors and exhibitors, institutions/agencies/organizations/individuals that support/sponsor the works of the Authors and the publishing/registration fees and related expenses.

I hope this MIMEC2013 Proceedings can benefit the authors, the readers, and public. It is intended that this conference series will continue and flourish. Please continue and extend your support to us. Pardon for any lack of service and inconvenience. Let us know how to serve you better.

Thank you and best wishes.

Denni Kurniawan
Editor, MIMEC2013 Proceedings
Organizing Chair, MIMEC2013
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The Effect of Cutting Parameters on Power Consumption during Turning Nickel Based Alloy

Rusdi Nur1,2,a, M.Y. Noordin2,b, S. Izman2,c and D. Kurniawan2,d

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Keywords: Power Consumption, Cutting force, Nickel Alloy.

Abstract. Machining process should also consider environmental aspect, with power consumption as one of the criteria. Cutting parameters can be optimized to minimize power consumption. This paper takes a study on turning of nickel-based hastelloy under dry condition (no cutting fluid) which varies cutting speed (150, 200, and 250 m/min) and depth of cut (0.5, 1.0, and 1.5 mm). Power consumption of particular machining process at various cutting parameters was derived and calculated. It was found that minimum power consumption was shown when the turning process was performed at the lowest cutting speed and depth of cut.

Introduction

Manufacturers, in particular machining centers, would save money and become more sustainable if their power consumption is minimized. Towards this aim, the machining processes should gather information on the power consumption [1]. There various ways to measure power consumption during machining. It is interesting to note that two third of the power is consumed for operating motors and driving the cutting tools [2]. This power consumption is high during roughing and is considerably lower during finishing [3]. This means, setting of cutting parameters (which determine whether the machining is a roughing or finishing process), have direct influence to the power consumption.

Determining the power consumption of machining processes is quiet complex, since it should take into account all aspects involved in the process, the workpiece, the tool, and the operator. For this, one can use the approach introduced by previous works. Hanafi et al. estimated cutting parameters in turning of PEEK-CF30 using TiN tools under dry machining, to attain minimum power consumption and the best surface quality using Taguchi and grey relational method [4]. Another work was a study into the effects of cutting parameters and nose radius in turning of 7075 Al alloy SiC composite to minimize power consumption and maximize tool life [5].

This paper present an approach derived from previous study to calculate power consumption during the turning process of nickel-based Hastelloy without cutting fluid. Generally, the calculation of power consumption is derived from cutting force data of the machining process.

Evaluating Power Consumption

During a machining process, energy is used to drive components (e.g., CNC control unit, spindle, and feed axis) of the CNC machine tool to conduct a series of operations (e.g., set up, loading, cutting, automatic tool change). Previous studies showed that the power consumption is dynamic during machining processes. In turning, the power consumption profile can be divided into three parts: constant power, variable power, and peak power (Fig 1). Peak power is usually short and contributes only a small portion to the cumulated energy consumption; thus it can be ignored when calculating the total energy consumption. With consideration of these states, the power demand can generally be differentiated into a variable and a constant power [6].

It was reported that the energy required for the material removal processes can be quite small compared with the total energy for machining process [6]. It was further suggested that the energy footprint for primary processes involved in material fabrication is usually higher than that for
secondary shaping processes [7]. Notwithstanding this factor, for manufacturing companies, the raw material inputs are usually defined by the customer and the energy calculation should only focused on the secondary production processes, i.e. the machining.

The electrical power requirement, P, for machining can be calculated from equation as follow:

\[ P = P_o + k \cdot \dot{v} \]  \hspace{1cm} (1)

where \( P \) is the power consumed by machining process, \( P_o \) is the power consumed by all machine modules for a machine operating without loading, \( k \) is the specific energy requirement in cutting operations, and \( \dot{v} \) is the material removal rate (MRR).

As shown in Eq. 1, the energy requirement for machining process is dependent on power consumed and specific energy in cutting operations. Representative specific energy for machining different materials was published by Kalpakjian and Schmid [8]. The values to adapt depend on the combination of tooling and workpiece material used. From on Eq.1, the total power for machining can be divided into two, namely the idle power \( (P_o) \) and the cutting power \( (P_c) \). The idle power \( (P_o) \) is the power needed or required for equipment features that support the machine (such as the power to start up the computer and fans, motors, and coolant pump). \( P_o \) can be estimated as 35% from total power capacity of lathe machine, considering it is common that the drive capacity of the spindle unit is overpowered (the maximum torque is two to three times higher what is necessary for the cutting process). The cutting power \( (P_c) \) is the product of cutting force and cutting speed \[9,10\]. The equation for the cutting power \([\text{Watt}]\) is:

\[ P_c = F_c \cdot V_c \]  \hspace{1cm} (2)

where \( V_c \) is the cutting speed in m/min and \( F_c \) is the main cutting force in N. Based on Eq. 1 and Eq. 2, the total power consumption in turning can be stated as:

\[ P_t = P_o + F_c \cdot V_c \]  \hspace{1cm} (3)

Case Study

This paper uses data and results of an experimented by Khidhir and Mohamed [11]. The machining was performed using a OKUMA 2-axes lathe machine with 11 kW spindle motor and 6000 rpm of maximum speed. The cutting parameters are stated in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Details of cutting parameters [11]</th>
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<tbody>
<tr>
<td>Cutting speed (m/min)</td>
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<tr>
<td>Depth of cut (ap) (mm)</td>
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<td>Feed rate (mm/rev)</td>
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<td>Coolant</td>
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</table>
Material for experimental trials was nickel based alloy (Hastelloy C-276) round bar to ASTM B574-99a specification (Hynes international). The material was annealed at 1120°C (held 75 minutes) and water quenched. Its chemical composition were: 57% Ni, 1.62% Co, 15.44% Cr, 15.34% Mo, 5.43% Fe, 3.67% W, 0.41% V, 0.52% Mn, 0.004% C, <0.02% Si, 0.005% P and <0.01% S. The cutting tool was ceramic insert (Sandvik) with specifications: 1.2mm nose radius, -6° rake angle, and inclination angle was designated as SNGN 120412E (45° of approach angle, K).

Results and Discussion

Experimentation of turning on the nickel based alloy indicated that the power consumption tends to increase for higher depth of cut. The power consumption has a proportional relationship with the cutting force as shown in Eq. 2. This indication was caused by the value of cutting force that also increases with increasing feed rate [11]. This can be seen in Fig. 2 which shows that the power consumption is proportional to feed rate and cutting speed.

![Power consumption vs Cutting Speed](image)

*Fig. 2 The graph of power consumption for different cutting speed at DOC 0.05, 0.10, 0.15 mm/rev*

The power consumption as showed in Fig. 2 was evaluated based on the data of cutting force using Eq. 3. The increment of power consumption was influenced by the data of cutting force that increases for not only increased cutting speed but also increased feed rate. This result is in agreement with the experimental study on machining of AISI 1045 steel that concluded that the power consumption continuously increases with an increase in cutting speed [12]. Similar result was also obtained during turning GFRP composites that cutting power is directly proportional to the cutting speed because the cutting power is the product of cutting force and cutting speed [9]. It should be noted that although the power consumption is the lowest at the lowest cutting parameters setting, the corresponding material removal rate is also the lowest. Hence, further analysis to optimize the conflicting objectives could be needed. An approach is by design of experiments which is capable of doing similar optimization of cutting parameters for turning processes [13,14].

Conclusion

In this paper, the power consumption of machining nickel based alloy Hastelloy C-276 was evaluated based on cutting force when dry turning. It also presented an approach in evaluating power consumption during machining which was proven to be applicable for the particular turning process. Cutting speed (150, 200, and 250 m/min) and depth of cut (0.5, 1.0, and 1.5 mm) were the variables. The results show that minimum power consumption would be obtained at the lowest cutting parameters.
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Journal Self-citation is defined as the number of citations from a journal citing article to articles published by the same journal.

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Citable documents Non-citable documents

Ratio of a journal’s articles including substantial research (research articles, conference papers and reviews) in three year windows vs. those documents other than research articles, reviews and conference papers.

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Nur, R. a, Noordin, M.Y. b, Izman, S. b, Kurniawan, D. b

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