

# Optimization of Hot Facing Process Parameters for Efficient Machining of High Carbon Steel

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## ABSTRACT

The modern manufacturing industry is under growing demand concerning the materials with excellent strength, durability and wear resistance. Nonetheless, machining hard materials of this kind poses great challenges due to the high cutting forces, high power consumption, and wear rate. These are not only demotivating in terms of productivity, but also they are cost raising in terms of operations. The current research solves this problem by proposing a controlled heat treatment process before the machining operation known as hot machining that entails heating of the workpiece to a reasonable temperature that improves the machinability of the workpiece without affecting its crystalline structure or degrading its natural mechanical characteristics.

The primary aim of the study would be to examine and show how this preheating stage impacts on power usage and tool wear in the facing process of hard materials like High-Speed Steel (HSS) and Stainless Steel. Both untreated ( cold machining) and heat-treated (hot machining) are subjected to experiments under the same cutting conditions. The important machining parameters like the cutting force, spindle speed, surface finish and tool life are measured and compared systematically.

Initial findings indicate that the heat-assisted machining process will significantly decrease the cutting resistance and power requirement besides cutting down on the tool wear. The formation of the softened surface layer through slight heating allows easier chip formation resulting in a smoother surface and increased dimensional accuracy. This research thus confirms that the implementation of controlled preheating before machining can significantly enhance productivity, reduce tool replacement frequency, and optimize energy consumption in industrial manufacturing. Consequently, the proposed approach offers a promising and cost-effective solution for efficient machining of hard-to-cut materials without compromising their structural integrity.

## Keywords:

Hot machining; High carbon steel; Tool wear; Power consumption; Surface finish; Machinability optimization

## 1.INTRODUCTION

Introduction: The history of the development of mass production technologies initiated by Henry Ford transfer lines defined the basis of the methods of production. The world workforce is spending a large amount of money every year. A lot of material is wasted in form of scrap or chips. Processing costs can be reduced greatly by choosing the right tools and processing conditions. Industrially, machinability is the ultimate factor to be considered when cutting metal and how it influences the economic efficiency of the

process. Researchers have expressed a great interest in machinability. A reduction in the costs of the materials is one of the main objectives of the process. Making a wrong choice may result in a high cost of production and a decrease in product quality. In the recent past, the industrial companies have been aiming at cutting down the costs of operation and improving quality. In the manufacturing industry, lowering the costs and improvement of the quality of the products is a vital step in an increasingly competitive environment, in which investors are seeking higher returns on their investments. Many manufacturing operations involve cutting operations, and require quantitative determination of the technological performance characteristics of an operation like tool life, strength, power and surface polish. The information is crucial in the choice and design of machine tools and cutting tools as well as optimization of cutting conditions in order to realize efficient and successful production. In the metalworking, cutting tool wear is the major factor and condition of the successful continuation of production. During the last 20 years, the machining of hard-to-cut materials elicited great interest in the industry. The increase in science and technology has brought about need to have materials that are very hard and can withstand shear in the industry. The need to manufacture some strange and intelligent materials has been significant in order to meet the strength requirements by the aerospace and defense industries. The manufacturing of superalloy and hard metal has become critical to meet design requirements of vital applications. Page nine Department of Mechanical Engineering; aerospace and defence sector. The handling of these materials has always been a major issue to the industrial engineering. These are used in manufacture of parts used in electrical, chemical, dental and orthopaedic, nuclear and aerospace industries where high dimensional accuracy, tool life and acceptable surface finish are needed. Durable materials used in the production process can greatly decrease the processing cost and lead times as opposed to the traditional procedures that may include machining metals, heat treatment, annealing and then proceeding on to the final stages of finishing such as grinding and polishing, all of which are time consuming, labour intensive in terms of effort and space. Optimizing the surface finish and tool life is not easy in machining of materials with such attributes as high strength, corrosion resistance, toughness, and wear resistance using conventional machining process. Their processing requires cutting tools of high strength, and these are usually prohibitively expensive, not to mention that they might not be available at all. This non-conventional machining process and other options that can be used are mainly limited to the removal of minimal material. The process of the bulk working of materials to be removed is increasingly gaining attention in the industry. This method encompasses heating of the workpiece, thus reducing the cutting force. 1.2 Hot machining: Tigham was the first to develop the hot machining process in 1889, and it has largely attracted the attention of other scholars. Hot machining is a machining process on regular machine tools, where the work piece is heated in advance of the cutting process to increase its malleability and later decrease its shear strength. The high operating temperature of the hot turning process results in the softness of the material under test that makes the machining operation easier and, therefore, leads to the reduction of the high costs of changing and sharpening cutting tools. On Page 10, there is a mitigation of the Mechanical Engineering Department. Hot machining is a more effective method compared to sharpening of the cutting tool used in conventional machining. Past investigations have

established that the proper choice of a heating means would reduce unwanted structural changes on the workpiece and lower the machining costs. The cutting tools made of more hard material than the workpiece material must be used to cut the steel that is hard to cut. Since cutting such materials is very expensive, a number of machining techniques are used. The formation of second phase particles is normally stronger and more abrasive and therefore it makes machining the alloy more difficult. Therefore, the advantage lies in the machining at the soft condition. It is due to notable effects of hot machining operations.

- Tool longevity is enhanced.
- There is decreased cutting forces.
- Reduced power consumption.
- Increment in productivity due to augmented Monthly Recurring Revenue (MRR).
- The workpiece strain hardenability and flow stresses are reduced.
- Wear and abrasion on the cutting tool is minimized resulting in a long tool life.
- Enhanced surface quality.

High temperature Hot machining can be easily used to handle delicate ceramic materials than any other machining technique.

1.3 Materials: Hot machining is used to machine hardened steel, high manganese steel, high carbon steel, NH4 (Ni-hard steel), superalloys, high chromium white cast iron, ceramic materials, hyperchrome cast iron alloys, chromium-molybdenum white cast iron, stainless steel, S-816 alloy, X-alloy, Timken 16-25-6, Navy grade Mechanical Engineering Department.

11. Heating Techniques.

1.4 Heating methods The hot working process will require the choice of heating technology. Minimisation of the affected region should be done. Hot operations should not penetrate deep into the surface of the material. Metallurgical changes occur in high temperatures and therefore overheating is always harmful, this should be avoided. The preheating of the workpiece should be done in the following ways:

1.5 Fundamental Requirements and Precautions of preheating the workpiece:

1.5 The heat should be concentrated in the cutting zone immediately next to the cutting edge where the material deformation of the workpiece is maximum. The heating must also be limited to a small section in order to reduce the swelling of the workpiece and this way dimensional accuracy is maintained. The means of heat supply should help to reduce the limitations of the dimensions, shape, and machining conditions of the workpiece. Machined surfaces should be kept clean and not subjected to too much heat, as it might cause metallurgical changes that might cause a distortion of the uncut material.

- The heat source should play a major role in specific heat so that the temperature can be responsive quickly at the interface of the tool.

The heating system to be employed should not only possess low initial cost but also the operational costs and low cost in terms of maintenance. The fact that safety is one of the priorities and that the used approach ought not to be hazardous to the operator. The temperature controller is also supposed to be very accurate.

## **2.Literature Review:**

### **1. Introduction to Hot Machining Techniques**

Hot machining is the use of a preheated moderate temperature workpiece such as a metal to be machined with the intention of minimizing cutting forces, energy usage and tool life. Different heating processes have been considered and these include induction heating, laser- assisted heating and flame heating. These methods are intended to make

the material in the local area soft so that it becomes easier to form chips and it also removes the mechanical load on the cutting tools.

## 2. Effects on Cutting Forces and Power Consumption

It has been found that when the workpiece is preheated, it is possible to drastically cut the forces and power usage in the cutting. In one example, it has been found that preheating to a temperature of about 300 o C can result in a 33 percent cut in force during milling processes and a 50 percent cut in the amount of tool wear MDPI. In the same way, it has been observed in other studies that cutting forces and specific cutting energy are reduced, which indicates the efficiency gains that could be obtained by the use of hot machining.

## 3. Tool Wear Reduction

The wear of the tool is a very important element that affects the cost and efficiency of machining. Preheating of the workpiece has also been found to contain the tool wear through decrease of thermal and mechanical stress of the cutting tool. To illustrate, it has been determined that preheating to 300 o C levels led to a 50 percent cut in wear on the tool in comparison with CMM MDPI. This is because with higher temperatures, the hardness of the workpiece will be lower and therefore the rate of friction and wear will be low.

## 4. Surface Finish Improvement

Parameters of machining process have a direct influence on the quality of machined surface. Preheating of the workpiece may enhance the surface finish through the facilitation of an easier flow of the chips and a decrease in the frequency of accumulated edges formation. Studies have indicated that preheating may result into a considerable rise in surface roughness which improves the overall quality of machined component ScienceDirect.

## 5. Modeling and Optimization Approaches

In order to maximize the hot machining parameters, several modeling and optimization models have been used. FEM has been applied to the simulation of temperature distribution and stress fields in machining and given information on how various parameters influence machining performance. Moreover, optimization techniques have been used to determine the best machining conditions to reduce cutting forces, power usage and tool wear and maximise surface quality using such optimization techniques as the Taguchi and the response surface methodology.

## 6. Identified Research Gaps

Despite the advancements in hot machining, several areas require further investigation:

- **Material-Specific Studies:** Most studies focus on materials like AISI 1045 or SKD11 steels. Research on high carbon steels, particularly AISI 1095, is limited and warrants further exploration.

- **Long-Term Tool Wear Analysis:** While short-term studies have shown tool wear reduction, long-term effects under industrial conditions remain under-researched.
- **Comprehensive Energy Analysis:** Detailed energy consumption studies, considering both the heating process and machining operations, are scarce and needed for a holistic understanding of energy efficiency.
- **Economic Feasibility:** The cost-effectiveness of implementing hot machining techniques in industrial settings requires more thorough economic analysis.

## CONCLUSION:

It is clear that metals that are hard to machine at room temperatures can be easily machine at high temperatures using the above results and related graphs It is evident that increased production rate will be achieved under the above results. we can increase the feed and depth of cut without altering the tool life whereas in conventional machining we cannot do so.

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