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Review

An overview of current status of cutting fluids and cooling techniques of turning hard steel

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A B S T R A C T

In the recent years, there has been increasing interest in hard turning over grinding for machining of hardened steels. There are some issues in the process which should be understood and dealt with such as friction and heat generation at the cutting area that can affect the tool life and surface finish apart from other machining results to achieve successful performance. Researchers have worked upon several aspects related to hard turning and came up with their own recommendations to overcome these problems. They have tried to investigate the effects of tool materials, cutting parameters, different cooling type and cooling technique on different machinability responses like tool life, surface roughness, cutting forces, chip morphology, etc. This paper presents a comprehensive literature review on cutting fluids and cooling technique on turning of hardened steels. Type of tools and cutting parameters used by the researchers have been summarized and presented in this paper as well to give proper attention to the various researcher works.

Contents

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1. Introduction

Conventional machining or traditional machining is cutting processes which remove the material from the various surface of a work piece by producing chips. The machine tools, such as lathes, milling machines, drill presses, or others, are used with a sharp cutting tool to remove material to achieve a desired geometry [1]. Conventional machining includes turning, boring, drilling, milling, broaching, sawing and so much many more.

Today, as the manufacturing technology changing rapidly, the demands on the better quality on the hardened part are increasing. Historically, grinding is more preferred as a method to machine hardened materials with high hardness for the final machining operation [2–6]. However, by the emergence of tool materials that have ultimate hardness, such as ceramic and cubic boron nitride (CBN) tools, has made it possible to circumvent the traditional machining practice for hardened steel. At significantly higher material removal rates, hard turning also can produce as good or better surface finish compared to grinding although grinding is known to produce good surface finish at relatively high feed rates [5,7,8]. Hard turning is defined as a process in which hardened steels (above 45 HRc) are finish turned. In other words, a lathe or turning center provides the last operation bringing the workpiece to final shape and surface condition. Hard turned parts do not need to be finish ground.

During the turning process, as Sharma and his co-worker [9] observed that between the tool and workpiece, the heat released and the friction often caused problems in terms of tool life and surface finish. This phenomenon is explained by Kalpakjian & Schmid in 2013 [1]. According to them, in conventional machining, there is contact between the tool and the material workpiece. The contact causes the friction force to occur. The increasing of friction can cause the tool to wear or broken as the structure the lathe tool has the sharp tip for cutting purpose. This is because cracks propagate due to sharpness of crack tip. The cutting condition has a considerable effect on the tool wear and surface roughness. On the other hand, the plastic deformation and crack propagation inside the work material, and process stability are influenced by these occurrences. Meanwhile, Bhuiyan et al. [10] reminded us, the tool wear is a normal phenomenon occurring in any metal cutting process. It dulls the tool cutting edge, increases the friction between the tool and the workpiece and also increases the power consumption.

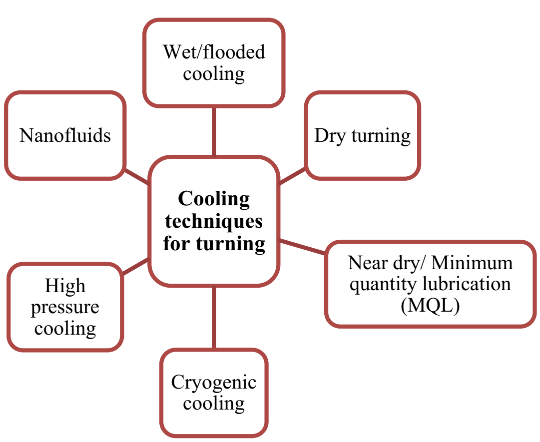

Fig. 1. Cooling techniques in turning hard steel.

Conventionally, cutting fluids have been used as lubricants and coolants to address these problems. Cutting fluids put in practice during machining operations to improve the tribological process, which occurs when the tool and the workpiece make a contact. Cutting fluids is really helpful in machining as it can increase tool life, surface condition of the workpiece and the process as a whole. Besides that, it also helps in reducing heat and carrying away debris produced during machining [11–13]. However, the use of cutting fluids has several adverse effects such as environmental pollution, dermatitis to operators, water pollution and soil contamination during disposal [14–16].

Many researchers have been researching on various aspects of hard turning and come up with their own proposals regarding the process. The process parameter is basically various forms of inserts, tool materials and coatings on process performance by different cooling technique. There are various cooling techniques in turning process however only the techniques shown in Fig. 1 will be described in this paper. A good amount of experimental studies and researches also have been done in order to understand the impact of process parameters on the cutting responses such as surface integrity, cutting forces and the tool wear or tool life through experiments as well as modeling. However, none of this previous research provides a picture of the comprehensive review on the use of cutting fluids. Therefore, this paper focuses in reviewing various cooling techniques, especially the use of cutting fluids, in turning hard steel materials.

2. Hard turning

In recent year, demand for extremely tough and hard steels is increasing in industry so that it creates challenges for machining operation to produce high performance or quality product.

In the manufacturing industry, the aim is to produce high quality products with lower cost and time constraints. Hard turning has been introduced as an effective and emerging metal cutting of steel with a hardness exceeding 45 HRc. Hard turning can be defined as the process of effective finish turning material using single point cutting tools which have high hardness (45–70 HRc) and high wear resistance [4,17,18]. Meanwhile, according to Bartarya and Choudhry [7], hard turning is a phenomenon of high-speed machining where the speed will typically 250 m/min, sometimes even more than this. High-speed machining for a given material also can be defined as that speed above which shear-localization develops completely in the primary shear zone [19]. Therefore, the ability of the machine tool should be including high rigidity, high surface speed, constant surface speed and high precision surface finish is required.

As a process involving machining of material that more than 45 HRc, therefore, tougher and harder tool materials with low wear capabilities is needed as the generated power and forces are expected to be high. Mostly, the researchers have used cubic boron nitride (CBN), Polycrystalline cubic boron nitride (PCBN) and coated CBN tool inserts for the purpose [5,11,20,21–24]. Some researchers have used coated carbide insert [25–32] as well as tungsten carbide coated with TiN [27,33–35]. Besides that, there are also a few researchers used ceramic (alumina) for turning hardened material [17,21,36–40].