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Applications of Solid Lubricants during Hard Turning- A Review

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Abstract: Hard turning is a widely used process in manufacturing industries. The superior surface quality and high wear resistance are the main features of hard turning. The selection of process parameters during hard turning is the critical deciding the machining performance. The main problem associated with hard turning is the high frictional heat generation during hard turning. Traditionally the heat generation can be controlled by using cutting fluids. However, due to strict environmental regulations, their uses in the industries become restricted. Therefore, there is need to investigate an alternate of cutting fluids. The use of solid lubricant during hard turning is an alternative to cutting fluids. Therefore, this research plans to review the applications of solid lubricants during of hard turning which not only reduces the temperature of the cutting area but also enhances the machining performance.

Keywords: Hard turning, Cutting fluids, machining performance, Solid Lubricants.

I. Introduction

Hard turning finds a wide range of applications in manufacturing industries such as automobile, tool and die, bearing and another engineering. The components produced during hard turning have close tolerance and high dimensional accuracy as generated during the grinding process. The hard turning using the advanced tool materials, such as cubic boron nitride (CBN), mixed ceramic and coated carbide has more advantage than grinding. The performance of hard turning process is analyzed from surface roughness, tool wear, cutting forces and cutting temperature. The performance of hard turning depends on numbers of process parameters such as cutting parameters cutting speed, feed rate, depth of cut), tool geometry, tool materials, workpiece materials and environmental conditions. The high machining performance during hard turning can only be obtained by selecting appropriate combinations of the process parameters.

In dry hard turning, the friction and adhesive between chip tool are very high, which causes high heat generation at the cutting zone, it leads to earlier tool wear rate, as results of which the machining performance is decreased. The high heat generation can be controlled by using cutting fluids during the machining. Cutting fluids work as a lubricant to reduce friction between chip and tool surface. The use of cutting fluids help in controlling the temperature of cutting zone that in turn enhance the machining performance.

However, the difficulties related to the use of cutting fluids are obtaining, storage, and disposal that comprise expenses. Moreover, it also leads to environmental pollution. Therefore, there is a need to investigating some other alternative techniques of lubrication. Solid lubricant technique is another option, which is environment-friendly as well as operator friendly. Therefore, this study has been carried out to investigate the applications of solid lubricants during hard turning.

II. Previous Work

Some researchers have explored the idea of using solid lubricants during machining. Shaji and Radhakrishnan examined the applications of solid lubricants during grinding. The studies show that the solid lubricants can act as an alternative to conventional cutting fluids. In another study, they observed high wear rate of the grinding wheel by the use of graphite as a solid lubricant when compared to CaF_2 as a solid lubricant. It is because of nature of bond in CaF_2 is fusion type and is robust than the bonding in graphite [1-2]. Gopal and Rao studied that the surface finished improved during the grinding of SiC by the use of graphite as solid lubricants [3]. Reddy and Rao reported that heat generation at milling zone was reduced by using graphite as a solid lubricant during milling of AISI 1045 steel. In another study, they examined that milling

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performance was significantly enhanced by the use of graphite and molybdenum disulfide as solid lubricants during milling of AISI 1045 steel [4-5]. Mukhupadhyay et al. reported that the surface quality was improved from 5% to 30% by applying molybdenum disulfide as a solid lubricant during machining of AISI 1040 steel [6]. Agarwal and Rao reported that heat generation and friction were reduced at grinding zone during uses of graphite and molybdenum disulfide as solid lubricants during grinding of SiC [7]. Damera and Pasam studied that surface quality was enhanced by the use of boric acid as a solid lubricant during machining when equated to a dry condition. It is due to the small coefficient of friction of boric acid which helps in reducing the cutting forces and temperature at the cutting zone [8]. Singh and Rao reported that the performance of machining process was enhanced by the application of solid lubricants during the machining. They observed that under similar conditions the performance of molybdenum disulfide was superior to graphite and dry conditions [9]. Rao and Krishna studied that among all particles size of solid lubricants, 50 µm size of boric acid as solid lubricants give a better performance during the machining of EN-8 than graphite particle.In another study, they formulated the surface roughness and tool wear prediction models by varying the size and flow rate of solid lubricants during turning. The results indicate that tool wear, and surface quality is roughness improved with an increase in flow rate of solid lubricant up to a certain level and remained constant at higher flow rates [10-11]. Reddy et al. investigated that tool life was improved significantly during drilling operations by the use of graphite as solid lubricant electro-statically, i.e., at high velocity and low flow rate. They concluded that solid lubricant mixture pierces the chip-tool interface and perform both cooling and lubrication functions that result in overall machining performance enhanced. In another study, they observed the overall improvement in machining performance and tribological properties by the use of molybdenum disulfide as a solid lubricant while machining [12-13].Vamsi et al. reported that solid lubricants such as graphite, calcium fluoride, molybdenum disulfide, and boric acid are alternative to cutting fluids during machining. The use of solid lubricants during machining helps in reduction of the coefficient of friction, cutting forces and tool wear more than cutting fluids [14]. Ramana et al. studied the influence of nano-level variation of solid lubricant boric acid particle size and its weight percentage on cutting forces, tool temperature and surface quality during machining of AISI 1040 steel. The results indicate that cutting forces, surface roughness, and cutting temperature are increased with a decrease in particle size [15]. Ojolo et al. investigated the influence of graphite as a solid lubricant during orthogonal cutting of carbon steel. The outcomes show that superior surface quality with solid lubricant assisted machining when compared to wet condition [16]. Iyappan and Ghosh evaluated the tribological properties of MoS2 and graphite-PTFE coatings during end mills of aluminum by HSS [17]. Padmini et al. studied the influence of micro and nano solid lubricants (boric acid and molybdenum disulfide) suspension in coconut and sesame oils on surface quality, cutting forces, cutting temperature, and tool wear during machining. The results show that performance of nanofluids is better than micro fluids [18]. Saleem et al. investigated the effects of different proportion of air and solid lubricant (boric acid) mixture along with particle size on surface quality and microhardness during grinding of AISI 1045 steel. The outcomes indicate that coarse particles and concentrated mixture give superior performance [19]. Kumar et al. studied the effects of cutting environments (dry wet and solid lubricant) on surface quality during hard turning of AISI 4340 steel using Taguchi approach. The superior surface quality was observed with the use of hBN solid lubricant when compared to wet and dry conditions [20].

A. Semi-solid lubricants

Instead of using only solid lubricants, some researchers have studied the effect of solid lubricant along with cutting oils. Krishna and Rao investigated that cutting forces and tool wears were reduced by varying the quantity of solid lubricant in SAE 40 oil during the machining of EN-8 steel. The outcomes indicate that 20% boric acid as a solid lubricant in SAE-40 oil gives superior performance than graphite. In their another study, they examined that the cutting temperature, tool flank wear, and surface roughness were reduced by using nano boric acid as a solid lubricant in SAE-40 oil during the machining of AISI 1040 steel [21-22]. Abhang and Hameedullah investigated that superior surface quality with small chip thickness were accomplished by the use of a mixed solid lubricant (10% boric acid + SAE-40) during the machining EN-31 steel [23]. Paul and Varadarajan investigated that the cutting performance was improved with the use of semi-solid lubricants (grease with10% graphite) during machining hard turning of AISI 4340 steel. They also determined that tool vibrations, tool wear, cutting temperature and main cutting force were reduced at 5mL/min, minimum fluid application rate [24].

Moura et al. analyzed the effect solid lubricants (graphite and molybdenum disulfide) suspension in cutting fluid during machining of the Ti-6Al-4V alloy. The results

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indicate that surface quality and tool life are improved. The cutting forces and cutting zone temperature are decreased with the use solid lubricant in cutting fluid during machining [25]. Paturi et al. (2016) observed about 35% improvement in surface quality during WS_2 solid lubricant assisted MQL machining of Inconel 718 than MQL assisted machining. It is because the presence of WS_2 helps in reducing tool-chip contact friction and temperature rise during the cutting process [26]. Gunda et al. reported that tool wear rate and surface roughness were reduced by utilizing high pressure with a minimum quantity of solid lubricant during machining [27].

It has been observed from the previous research work that there are many benefits of using solid lubricants during hard turning. The environmentally friendly nature is the main advantage of using solid lubricants. The solid lubricants have excellent lubricating properties, and they can withstand at high temperature during machining. The solid lubricants keep the sharpness of cutting tools during machining, which leads to providing better surface quality and high tool life than dry and wet conditions.

III. Conclusions and Scope of future work

The previous study shows that the solid lubricants play a significant role in enhancing the machining performance during hard turning. Some researchers have explored the idea of using solid lubricants like graphite, molybdenum disulfide and calcium fluoride during the machining process. However, Wang et al.[28] discovered that some metal compound could be used as solid lubricants such as metal oxide, halide, sulfide, selenide, borate, phosphate and organic salt. Therefore, there is scope to analyze the effect of some other kinds of solid lubricants during hard turning.

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