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# Innovative Techniques of Enegy-effeciency in Machining

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**Abstract**

This paper presents an analytical approach to characterize the relationship between energy consumption and other parameters, which affect the energy consumption in cutting operation and the input electrical energy of the machine. A reliable prediction of energy consumption will enable industry to develop energy saving strategies during various machining operations. To verify its feasibility and validity, the assessment method is applied to small machining workshop. This paper focus on the following areas: (1) Effect of automation on energy consumption during machining. (2)Effect on energy consumption due to defects during machining.(3)To find the optimal range of friction during machining processes, so that energy wasted in form of heat may be minimized and its impact on environment can be reduced. Along with this certain modifications for the existing system (for increasing the energy efficiency) are also proposed.

**Keywords**: Cutting Operations; Energy Consumption; Automation; Defects; Friction and Heat Generation.

## 1. Introduction

The manufacturing community is trying to reduce the energy consumption due to the energy cost problem, ecological and environmental policies. The methods for energy efficiency at the production or factory level in many manufacturing aspects are being intensive studied. On the one hand, different studies underline the significant potential for improving the energy and resource efficiency in manufacturing companies –certain numbers range from 10-40% of possible savings which can be achieved even with available technology Energy efficiency becomes a driver for manufacturing industry, since it is historically one of the greatest energy consumers and carbon emitters in the world. The manufacturing sector is responsible for about 33% of the primary energy use and for 38% of the CO2 emissions globally . During the last 20 years, an increase in energy prices of up to 100% has been recorded in Germany Energy savings are expected to be achievable from increasing both the energy efficiency of production and the logistic processes, as well as in innovative energy monitoring and management approaches , leading industries to a way of producing “more with less” . China, manufacturing spends around 50% of the entire electricity produced , and generate at least 26% of the total CO2emissions. The environmental awareness leads the EU member states agreeing on the principle of “20/20/20 by 2020”, i.e. a 20% reduction in greenhouse gases, a 20% share of renewable energies and a 20% increase in energy efficiency by the year 2020 as compared to 1990 indicators . Manual and CNC machines are widely used in machining industries. Manual machines are usually used as spare machines in the shop floor. They are also used to produce low quantities components. The comparison of the energy consumption between manual lathe and CNC will be carried out. In turning processes the cutting force acting on the cutting edge of the tool can be resolved into three components the longitudinal force, the radial force, and the tangential force. Material removal mainly involves only two cutting forces, when turning these are: (1) Axial force (2) Tangential force. The thrust force is decreasing with increasing cutting speed in case of machining with HSS or HSS coated, but increases in case of machining with carbide tool then again decreases when speed is increase during turning of aluminum.

## 2. Optimized Automation

Referring to lathe machining operations, the numerical control machine has higher power consumption compared to manual one . A factor that affects the high energy consumed in the CNC lathe machines was due to different types of auxiliary units installed in the machine modules. For example, the axis motor and motor used to hold the machine turret during machining processes. The popularity of CNC machine is due to their capability of CNC machines to produce higher quantity of components in shorter time compared to manual ones. On the other hand, high use of CNC lathe machines increases power consumption and hence makes the target of supporting sustainable machining difficult to reach. Therefore, to help in solving this problem, this research tries to reduce energy consumption especially in lathe machining process by atomizing some of the components of lathe machine. For example the supply of coolant during machining can be automated in the way that the coolant pump is actuated only when the value of temperature at tool chip interface increases beyond a certain preset value. The temperature sensing at the tool chip interface is done by means of an IR Thermometer. By incorporating this technique we can reduce the energy consumed n=by the coolant pump during idle running and the time when the temperature is below the pre set value (preset value - It is the value of temperature below which the machining can be performed without the need of coolant. Most of the researches takes into consideration either completely dry cutting or wet cutting through the process. But by the use of this arrangement the case of partial dry or wet cutting can be taken into consideration. The previous researches show that total energy given to the machine a substantial part of it is consumed in spindle running. Thus, the above suggested technique if implemented can minimize the total power consumed by the machine by eliminating the power given to the spindle at the time of idling and the time when the temperature is below the pre set value.

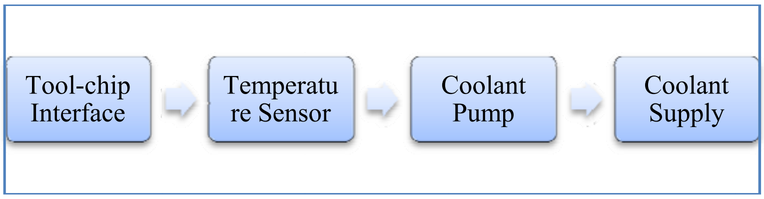


**Fig. 1**: Automation of coolant supply.

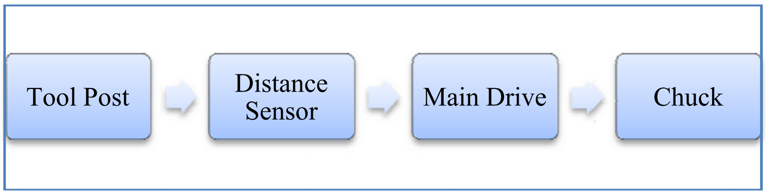


**Fig. 2**: Automation of chuck movement.

It is evident from past researches that out of the total energy supplied to the machine a substantial portion of it is consumed in non- machining operations . Thus minimizing this energy can improve the overall energy efficiency of the machining.

## 3. Cutting Power Analysis

In HSM, cutting speed has a predominant effect on the cutting temperature and the heat transfer mechanism. As cutting speed increases, the cutting process becomes more adiabatic and the heat generated in the shear deformation zone cannot be conducted away during the very short contact time in which the metal passes through this zone. In the metal cutting process, the tool performs the cutting action by overcoming the shear strength of the work piece material. Temperatures in the cutting zone considerably affect the stress–strain relationship, fracture and the flow of the work piece material. It is now assumed that nearly all of the work done by the tool and the energy input during the machining process are converted into heat. Firstly, heat is generated in the primary deformation zone due to plastic work done at the shear plane. . Secondly, heat is generated in the secondary deformation zone due to work done in deforming the chip and in overcoming the sliding friction at the tool-chip interface zone. Finally, the heat generated in the tertiary deformation zone, at the tool work piece interface, is due to the work done to overcome friction, which occurs at the rubbing contact between the tool flank face and the newly machined surface of the work piece.

The rate of energy consumption in metal cutting is given by:

$$W_c = F_v . V$$

Where $F_v$ is the cutting force in N and V is the cutting speed in m/s.

Assuming that all the mechanical work done in the machining process is converted into heat, then heat generation, $Q_s$ in J/s in the primary deformation zone may be calculated from the work done as:

$$Q_s = W_c = F_V . V$$

where, $F_V$ is the tangential cutting force or the force in the velocity direction and V is the cutting velocity.

The amount of heat generated due to the work done in the secondary deformation zone along the tool rake face is calculated from the friction energy given by the following equation:

$$Q_r = F_{fr} . V / R_t$$

Where $F_{fr}$ is the total shear force in N acting on the rake face, and $R_t$ is the chip thickness ratio. The force $F_{fr}$ can be calculated by using the following equation:

$$F_{fr} = F_v \sin\alpha + F_s \cos\alpha.$$

| Feed=0.13mm & Rake angle =50, Dia of Al alloy=57mm | | | | | | |
|---|---|---|---|---|---|---|
| **S. No.** | **Speed (rpm)** | **Cutting Force(N)** | **Tangential Force(N)** | **Shear force(N)** | **Chip thickness ratio** | **Cutting power(W)** |
| 1 | 90 | 452 | 655 | 158.3 | 0.41 | 120 |
| 2 | 140 | 520 | 731.5 | 255.32 | 0.33 | 210 |
| 3 | 215 | 639 | 795 | 360.56 | 0.32 | 400 |
| 4 | 330 | 743 | 812.3 | 466.79 | 0.30 | 720 |

As we see from table the power consumption increases with speed and heat generation in primary shear zone is equal to cutting power, so HSM (high speed machining) contribute more in green house effect.

## 4. Energy Consumption Due to Defects

Experimental investigation shows that tool flank wear does not statistically affect the basic cutting quantities such as the shear angle and shear stress, both qualitatively and quantitatively, but results in an additional rubbing or ploughing force on the wear land. The study also shows that tool flank wear results in a substantial increase in the force components and that the thrust force is more sensitive to tool flank wear. Oxley et al. argued that although practical machining operations use more geometrically complex cutting tools than the wedge tools used in orthogonal cutting, the basic material removal process is always the same. In orthogonal cutting the resultant cutting speed V and the chip flow speed $\boldsymbol{V_c}$ are perpendicular to the cutting edge. In the vast majority of orthogonal cutting analyses , the cutting process is represented by a plastic shearing process in a localized (i.e. thin) shear zone or plane (AB) and a friction or secondary shearing (seizure) process at the tool-chip interface. It has been suggested by many researchers that since the cutting edge is not perfectly sharp, a rubbing or ploughing process could occur in the vicinity of the cutting edge resulting in an edge force in addition to the force due to the chip formation in the shear zone. As it was discussed earlier, the rate of tool wear strongly depends on the cutting temperature; therefore, any measures which could be applied to reduce the cutting temperature would reduce the tool wear as well. The figure shows the process parameters that influence the rate of tool wear:

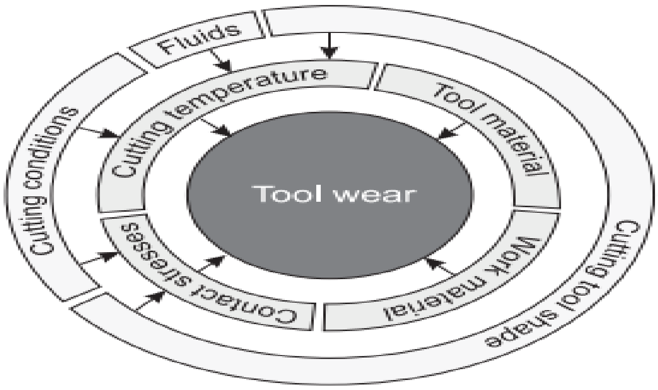


**Fig. 3**: Parameters affecting tool wear.

As the figure shows that cutting temperature , cutting conditions and contact stresses play a significant role in tool wear so above proposed method of temperature controlled coolant operation will decrease the chances of wear as well as saves energy.

## 5. Conclusion

This paper presents an integrated concept to increase energy efficiency in machining workshop on different layers. A simplified and practical energy efficient method is advanced in this paper, where the startup energy, idle power and power of additional load loss are minimized by automation, and material removal power is calculated by theoretical formulas according to process parameter. Reduction of the energy consumption can be realized by optimizing the energy consumed by coolant pump. This study shows that the traditional minimum cost criterion does not necessarily satisfy the requirement for minimum energy. Given that non-cutting operations consumed most of the energy in machining, so a method is proposed to reduce energy consumption in non cutting operation in manual machines.

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