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Heat Assistive Machining Techniques: A Review on Turning Operation

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***Abstract:** In the modern times, there is a need of materials with very high hardness and shear strength in order to satisfy industrial requisites. So various materials which serve the properties are manufactured. Costly cutting tools are required to machine those materials. On account of increasing demands in industries, any furtherance of traditional machining process or any other deployment of additional technique is directly related to higher productivity. Thermal machining is other possible path for machining those hard materials using low cost cutting tools.*

The present paper deals with recent trends and challenges faced by the metal cutting industries in the case of machining of very hard materials. And a detailed review on thermal machining process specially in terms of turning operations were catalogue. The paper also focuses on the overview of thermal assistive machining process, machinability and reasons for development of new cutting tools in detail.

***Keywords:** Hard materials, heating methods, machinability, thermal machining*

I. INTRODUCTION

Manufacturing processes are classified into two main groups and they are primary and secondary manufacturing processes. The primary ones provide basic shape and size to the material as per need of the designer. Secondary manufacturing processes provide the final shape and size with appropriate control on dimensions, surface characteristics etc. However, material removal processes are mainly secondary manufacturing processes.

Material removal processes also divided into two groups and they are traditional and Non - traditional machining processes. Conventional machining is a mechanical energy based process and Non-conventional machining utilizes other forms of energy like thermal, electrical and chemical basis.

Heat machining method comes under thermal metal removal processes. The material removal rate decreases with an increase in hardness of the work material. It has been realized that such materials are difficult to machine by traditional methods and therefore the cutting business not only costly but also results into poor surface finish, dimensional tolerances and minimal tool life.

II. PRESENT MACHINING TRENDS & CHALLENGES IN INDUSTRY

With expansion in science and technology, there is a need of materials with very high hardness and shear strength in the market. So many materials which satisfy the properties and design requirements are manufactured. Development of difficult and harder to cut materials such as hastalloy, carbides, high manganese steel, stainless steel, heat resisting steels and various other high strength temperature resistant (HSTR) alloys.

These are used in aerospace industry, nuclear engineering and other industries due to their hardness, high strength to weight ratio and heat resisting quality.

In manufacturing industry, machining of hard materials using grinding process results in low material removal rate, not flexible and time consuming.

Hard turning operations comprises of new tool materials, which are 15-20 times costlier than others. Utilizing cryo-machining in the cutting of hard materials also includes high investment cost and skilled operator. Again non-traditional machining processes are high in investment cost with low material removal rates.

The industries always face problems in machining/manufacturing of components because of some stress produce in the metal being cut. Non-traditional processes mean in the sense that they do not employ traditional tool for material removal but they use some form of energy for machining. Advance non-conventional machining methods, its main-advantages and disadvantages are as following.

Table 1: Non-conventional machining methods, its main-advantages and disadvantages

Machining methods	Advantages	Disadvantages
Electro chemical machining	Difficult-to-machine geometries Little or no tool wear	Initial tooling can be costly & timely, Environmentally harmful
Abrasive jet machining	Easy machining of hard materials Investment cost is low	Low MRR Nozzle life is less
Electro beam machining	Easy machining of highly reactive materials Produce very small holes (100µm-2mm)	Low MRR High skill operator required
Electro discharge machining	No distortion to machined parts Complicate shapes can produced	Low MRR Rapid tool wear
Laser beam machining	Produce extreme edge parts or zero edge deformation, Reduces wastage	Thermal expansion- problems Costly to run

III. LITERATURE REVIEW

Table 2: Literature review summary in referred journals: -

Author's name	Work/tool material	Heating method/Analysis	Studied	Most Significant affecting factors	Detections
J.Goudhaman (2007)	Nickle-chromium steel(600HB) SNMG carbide insert	Gas flame heating/ Taguchi/Minitab	Surface roughness, tool life	Cutting speed	Power required is reduced and tool life increase by 14.83 %
M.Davami (2008)	AISI 1060 steel TNNM 120408-SP10	A gas flame heating/ Plot Analysis	Surface roughness, tool temperature	Temperature Cutting speed	Increase in temperature tends to less variation in Ra,
Dr K. P. Maity (2012)	High-manganese steel Carbide tool	Automatic gas flame heating/Taguchi/ANOVA	Surface roughness, tool life	Spindle speed(rpm)	Tool life increases with decrease in yield stress of work piece, but increases tool wear rate
S.Ranganathan T.senthilvelen (2011)	Stainless steel (316 type) Tungsten carbide(WC) tool	LPG flame heating up to 600^0 C/Grey relational /ANOVA	Surface roughness, MRR and tool life	Feed rate, Cutting speed	Surface improvement can be achieved by combination of optimal parameters
Maher baili, Vincent Wagnor (2011)	Titanium alloy Ti-5553/CNMG 160612-QM	Semi-conductive inductor type heating up to 750^0C / Correlational analysis	Cutting forces Tool wear Surface integrity	Temperature Cutting speed	Surface micro structure may be changed
Mrs.swetha patil, Nithin K.kamble (2013)	En 36 (40 HRC)/ TiAlN coated carbide insert	Oxy-acetylene flame heating up to 400^0 C/ DOE / Grey relational	Surface roughness, MRR and tool wear	Temperature Depth of cut	Hot machining may also use for finishing operation too
Vikas Upadhyay, P.K.Jain (2013)	Ti-6Al-4V alloy/ CNMG 120408 Coated carbide tool	LPG flame heating up to 500^0 C / Chip analysis	Cutting forces Surface roughness Flank wear	Temperature	Cutting forces reduces with increase in temperature, but surface roughness may increases
Venkatesh Ganta, D. Chakradhar (2014)	15-5PH martensitic Stainless steel (40HRC)/ K313 carbide tool insert	Oxy-acetylene flame heating up to 350^0 C / S/N ratio / Grey relational	Surface roughness, MRR	Feed rate Cutting speed	Hot machining reduces cutting forces, which also reduces Ra with suitable cutting parameters
Ketul M. Trivedi, Jayesh V. Desai(2014)	AISI 4340 steel (90HRC)/ Tungsten carbide tool insert	Oxy-acetylene flame heating up to 600^0 C / DOE / ANOVA	Surface roughness	Feed rate Cutting speed	Hot machining increases ductility of work material, which increases feed rate and production rate.
MR. Jadhav, UA. Dabade (2016)	Al/SiCp (MMC)/ PVD coated CNMG120408 insert	Resistance heating(RT) up to 100^0 C / Taguchi method / Grey relational	Surface finish Flank wear	Feed rate Depth of cut	Surface of MMC material is damaged with increase in temperature
Harpreet Singh, Er. Sandeepsharma (2016)	En 8 steel/ Carbide insert CNMG12408	Butane torch flame heating up to 430^0 C / Comparison b/w dry and thermal machining	Surface roughness, MRR	Temperature	It is easy to shear of the hard materials, hence with minimum Ra and Maximum MRR
Adamu Umar Alkali, Turnad Lenggo Ginta (2016)	Stainless steel(316L)/ Uncoated (WC-CO) insert	Oxy-acetylene flame heating up to 600^0 C / RSM / ANOVA	Surface finish Tool life	Focus height Pressure Time	Controllable variables of heating method also affects the system of heating the workpiece
L. Ozler, A.Inan(2000)	Austentic manganese steel (243HB)/ M20 sintered carbide tool	LPG flame heating up to 600^0 C / mathematical model	Tool life	Cutting speed temperature	Poor conductivity materials gives poor surface finish in hot machining methods
Nihat Tosun, Latif Ozler(2004)	High manganese steel (200 HB)/ M20 sintered carbide tool	LPG flame heating up to 600^0 C / Taguchi method	Surface finish Tool life	Cutting speed temperature	Moderate temperatures are optimum, if we consider the micro-structure & cost of the work piece

IV. OVERVIEW OF THERMAL ASSISTIVE MACHINING PROCESS

In heat machining, heat is applied to the work piece to reduce its shear strength in the shear zone. The hot machining has become very useful in the machining of alloys like High strength temperature resistant. Hot machining has two functions to perform, one to increase the machinability of difficult to cut materials. Second, to improve tool life this actually improves the rate of production.

A. Main Requirements Of Heat Machining Process

1) External heat is applied to just ahead of the cutting edge, i.e. where the deformation of the material is maximum.
2) A fine temperature control device should be there in the method of heat supply, i.e. to avoid distortion to uncut material.
3) A large specific heat input must be supply by the heat source to create a rapid response in temperature a head of the tool.
4) The Heating method should be low in initial and maintenance cost and essentially not hazard to the operator.

There are various methods of heat machining which are subjected to requirements. Here the temperature of the work piece is heated to several hundred or thousand degree Celsius above ambient temperature.

Table 3: Various methods of heat machining

Heating methods	Advantages	Disadvantages
Furnace heating	Simple and relatively cheaper	Distortion on cooling
Flame heating	Large specific heat inputs are possible	Localization of heat is difficult
Arc heating	High specific heat inputs can be supplied	Heating is not very uniform
Resistance heating	Easy to handle No distortion on cooling	Temperature obtainable is limited
Plasma arc heating	A very high specific heat is achieved	Heating is not stable
Inductive heating	Quick temperature raise	Depth of penetration is limited
Radio-frequency resistance heating	Heating takes place over small area	Work piece must be magnetic
Electric current heating	Easy adaptable and control	Tool material must be magnetic
Friction heating	Initial and operating costs low	Cannot be used for intricate shapes

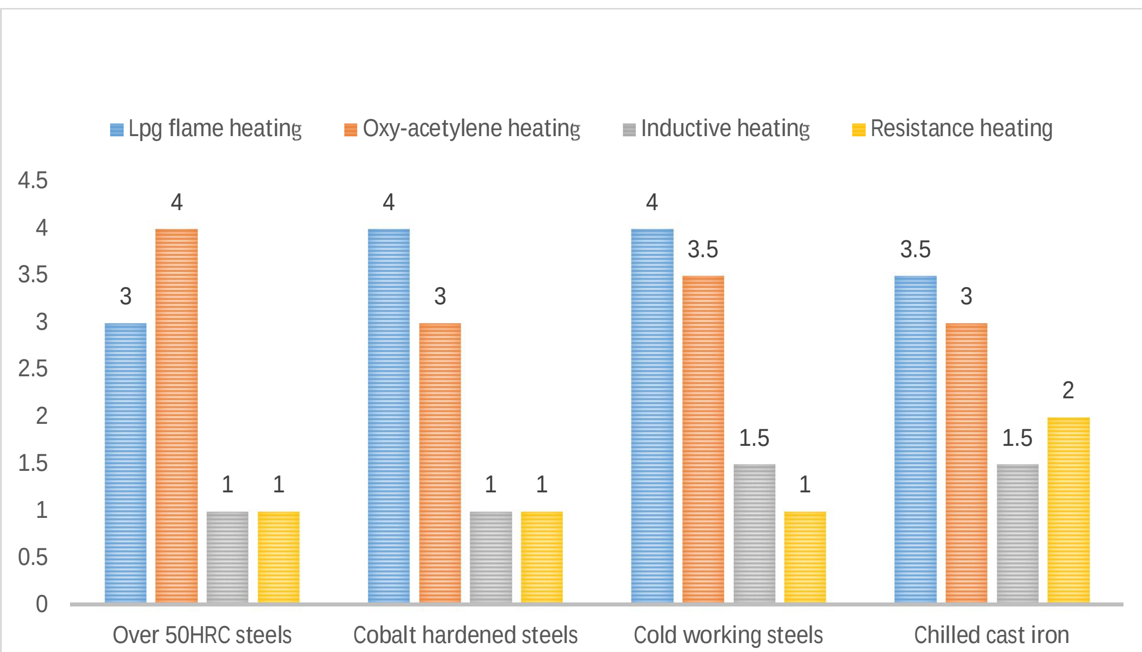

Figure 1 Different heating techniques used in referred journals for Heat Machining Group materials

B. Machinability Of Heat Assisted Machining

Machinability is the property of a system that indicates how the material is easily machined at low cost. Machinability concept always look into quantitative measures of tool life in minutes, cutting forces and power consumed, quality of surface finish, chip formation and material removal rate.

Production process can affect some functional parameters such as mechanical properties (strength, hardness, ductility and resistance to environment), tolerances, resistance to corrosion, electrical properties, thermal properties, surface finish and lastly appearance.

High strength means it increases metal cutting forces, specific energy, and cutting temperatures. High hardness increases abrasive wear, so tool life reduces and high ductility results tearing of metal as chips, causing wastage problems and poor surface finish.

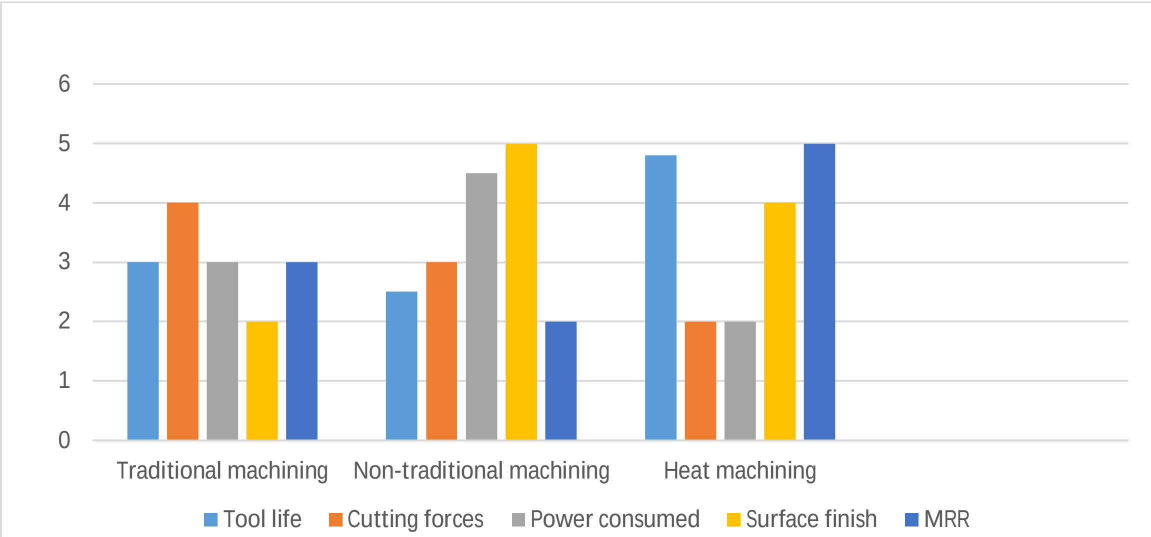

Figure 2 Machinability rating of difficult-to-cut materials in referred research journals

C. Reasons For Development Of Cutting Tool

The high operating temperatures in heat machining method imparts softening on the material, which eases the machining process and next reduces high changing cost and sharpening cutting tools.

1) *Global Vying:* Individual machining applications required separate cutting tools, the engineers or machinist do errors when choose tooling in calculating economic savings based on low cost per tool, preferably than on long tool life and maximized productivity. According to metal cutting science, the best cutting tool includes the following attributes; harder than work piece, impact and wear resistant, high temperature stability and chemically inactive to work piece and cutting solution. It is impossible that one cutting tool having all these qualities, because for example ceramic cutting tools has high temperature resistant, but has low impact resistant.
2) *Quality and Reliability:* The development of newer and newer cutting tools is to obtain good surface finish, high accuracy and dimensional tolerances in machining.
3) *Cost:* To reduce non-productive cost and unnecessary cost.
4) *Efficiency:* To control cutting speed, reduce cutting time and improve tool life. In traditional machining process softening of work piece is more effective way than strengthening the cutting tool.

V. CONCLUSION

Heat machining techniques solely reduce the development of new cutting tools for conventional machining and applications of non-conventional machining processes. The materials over 50HRc hardness steels, cold working steels (high manganese steels and Austenitic manganese steels), cobalt surface hardened steels and chilled cast iron are the heat machining group of materials. Oxy-acetylene gas flame technique is frequently adapted for high hardness materials in the past research works due to its low equipment cost and feasibility. Thermal assistive machining process have maximum machinability ratings compare to traditional and non-traditional machining process. On other side the micro-structure of work material damages, so micro-structural morphological studies have been expected from the present researchers of this domain.

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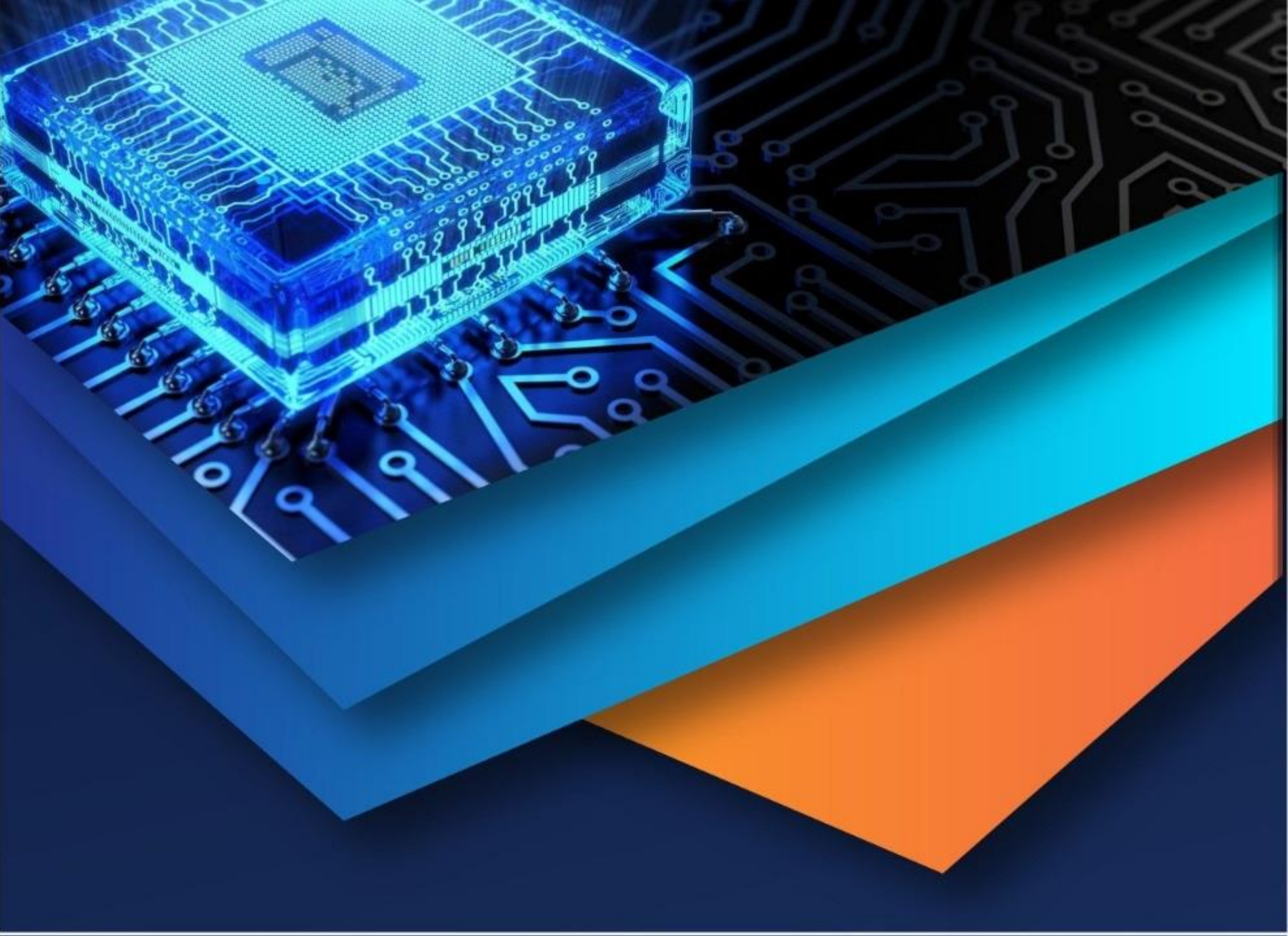

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