ISSN: 0974-5823 Vol. 7 (Special Issue, Jan.-Mar. 2022)

International Journal of Mechanical Engineering

Maximizing material removal rate in turning 42CrMo4 steel by comparing novel hard machining and flood cooling machining approaches

S. Gokul[1], N. Senthilkumar[2]

[1]Research Scholar, Department of Mechanical Engineering, Saveetha School of Engineering,
Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India -

[2]Project Guide, Corresponding Author, Department of Mechanical Engineering,
Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences,
Saveetha University, Chennai, Tamil Nadu, India - 602105.

Abstract:

Aim: The research is about maximizing material removal rate by novel hard machining and flood cooling approach using advanced inserts like Cubic Boron Nitride (CBN) and Poly-crystalline Diamond (PCD) in the turning process. **Materials and methods:** 42CrMo4 is selected as workpiece material and the inset used are PCD and CBN, Hard turning is considered as an experimental group and Flood cooling as control group which is innovative and novel in this work. Cutting depth, rate of feed and speed of cutting are the cutting parameters used in this procedure. The given parameters are used to machine a total of 36 samples. **Result:** The average MRR for the hard turning is 48.4311 g/min and for flood cooling is 67.0467 g/min. The significance value achieved by hard turning and flood cooling is 0.003 ($p<0.05$). **Conclusion:** The outcome of the research shows that the rate of material removal is maximum in flood cooling compared to hard turning.

Keywords: Novel Hard Machining, Green Machining, Die steel, PCD insert, CBN insert, MRR.

INTRODUCTION

In this work, the primary objective is to compare the performance of novel hard machining (turning) and flood cooling approaches during turning die steel towards increasing productivity through increasing the pace of material removal (Senthilkumar, Tamizharasan, and Anandakrishnan 2014a;Dinesh et al. 2016;) in a CNC machining center. Turning is the removal of undesirable material from a revolving workpiece to obtain a desired shape and size of component. If the process does not utilize any coolant then it is known as green machining. Green machining eliminates the risk of environmental pollution arising out of vaporization of coolant at the interfaces. CNC machines are employed to do machining with a high level of surface quality and dimensional accuracy. The component under research is 42CrMo4 die steel, a chromium-molybdenum steel with high intensity and hardenability after quenching and tempering. The alloy steel 42CrMo4 offers greater hardenability and strength (Biermann et al. 2013). The 42CrMo4 alloy offers a high fatigue life as well as strong low-temperature impact strength. Potential applications of 42CrMo4 includes gear, connecting rod, engine cylinders, crank shaft.

In the last five years, similar to this research work, 5300 journal papers are available in google scholar and 1350 journal papers published in sciencedirect. Das et al. (2019) carried out dry hard turning considering L_{27} array for optimizing flank wear, chip thickness, chip morphology, MRR, tool temperature, dimensional deviations and roughness and determined that cutting depth influences the surface roughness higher although the most significant input parameter of MRR was feed rate (Das, Hotta, and Biswal 2019). Turning of cutting rock with round RNGN inserts and dome buttons was studied, and it was discovered that tools made of cemented carbide exhibited comparable wear processes regardless of tool shape, and PCD outperformed cemented carbide in terms of resistivity towards wear. (Johansson et al. 2019). Kim e tal. (2016) performed hard turning studies on AiSI 52100 by fabricating micropatterns by layer-by-layer on CBN using EDM machining and observed reduction in resultant forces by 2.5∼10.9% using the micropatterned insert and reduced tool wear by 9.7∼11.4% in comparison with inserts having non-pattern. Friction is reduced due to greater shear deformation caused by air gaps on the inserts due to micropattern (Kim et al. 2016). The material removal rate is mainly influenced by the rate of feed and cutting depth, the taguchi's optimisation method is an effective way to identify the optimum cutting parameters for achieving optimum MRR (Sudharsan 2020). Moreover, our workforce has extensive expertise working on a variety of research initiatives across several fields (Samuel et al. 2019; Johnson et al. 2020; Venu, Subramani, and Raju 2019; Keerthana and Thenmozhi 2016; Thejeswar and Thenmozhi 2015; Krishna and Babu 2016; Subashri and Thenmozhi 2016; Sriram, Thenmozhi, and Yuvaraj 2015; Jain, Kumar, and Manjula 2014; Menon and Thenmozhi 2016)

Based on all these findings it has been determined that lower efficiency is the most important factor to improvise in novel hard turning or green machining. As a result, the study's aim is to compare and determine the efficiency of innovative hard machining with flood cooling approaches in terms of optimizing MRR to increase productivity. PCD and CBN tool inserts are considered in this work to improve the performance through higher MRR.

MATERIALS AND METHODS

The sample material used for the turning process was 42CrMo4 and the insert which was used for machining are PCD and CBN inserts (Xu, Zhao, and Ai 2017). This research is performed at Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. CNC controlled machining center having 500 mm swing with 260 mm carriage swing with 320 mm maximum diameter of turning and 400 mm length of turning, No of stations 8, distance among the centers of 425 mm and 3500 rpm spindle speed of maximum range. This project includes two groups (an experimental group and a control group). In this process, 42CrMo4 with hard machining is considered as an experimental group and turning with flood cooling is set as a control group. The sample size used for novel hard machining is 18 and for flood cooling is 18 (Senthilkumar, Selvakumar, and Tamizharasan 2016).

With high wear resistance and very favorable core properties 42CrMo4 tool steel is found to be suitable for high-stress components (including large forged parts) in vehicle, engine, and machine engineering (e.g. crankshafts, pinions, balance shafts). Static and dynamic loading are both resistant to the steel. -40°C is the lowest temperature at which you can operate. More mounting components will be used at a higher level. 42CrMo4 elemental constituents are shown in Table 1**.**

A polycrystalline pattern formed by sintered diamond particles, giving in a wear-resistant hard material with strong heat conductivity, allowing heat to be easily extracted from the cutting edge is commonly known as polycrystalline diamond (PCD) cutting tool. PCD is a synthetic substance that is sintered at a high temperature and pressure. Fig. 1 shows a PCD insert commonly used for machining high-silicon aluminium, non-ferrous metals and other non-ferrous metals. The nomenclature of PCD insert adopted in this study is TNMG 160408H.

One of the most important benefits of hard part turning is the ability to cut dry (Senthilkumar and Tamizharasan 2015). Cutting temperatures of over 1,000°C are no concern for cubic boron nitride (CBN) inserts. CBN has a positive effect on tool life in dry conditions in general, particularly in interrupted cutting. The nomenclature of the CBN insert used here is TNMG 160408. It was obtained from GTK tools and services, Tamilnadu Chennai which is shown in Fig. 2. The turning was done in the Super Jobber CNC turning center as shown in Fig. 3.

In the tool holder, the cutting tool was positioned and the total setup was placed in the tool drum. In the headstock the workpiece was set. Cutting depth (mm), rate of feed (mm/rev) and speed of cutting (m/min) are among the parameters that have been selected and are kept constant.

To measure the material removal rate (MRR), a workpiece with a diameter of 25mm and a length of 50mm is machined. PCD and CBN cutting inserts are used in the machining process for turning 27 samples. For both PCD and CBN inserts, the material removal rate per unit time is recorded for each experiment trial. A weighing machine is used to determine the weight of the specimen prior to the machining process. During machining, a stopwatch is used to monitor the time, and the weight of the specimen is measured afterward. MRR is determined using the weight difference (Tamizharasan and Senthilkumar 2012). The following simple formula was used to measure the rate of material removal. Equation (1) shows the formula to determine MRR in the turning process.

$$MRR(g/min) = (\text{Difference in weight before and after machining}) / \text{machining time} \quad (1)$$

Statistical Analysis

The mean, standard error, and standard deviation are measured using SPSS v.26 statistical software. When the probability value $p>0.05$ is used, the significance degree is taken into account. Type of cutting insert and method of machining are the independent variables in this study, while material removal rate is the dependent variable (MRR).The outputs are evaluated by an independent sample T-test to assess the importance of hard machining and flood cooling approaches.

RESULT

The measured MRR values for both hard machining and flood cooling is noted and tabulated in Table 2 for a constant value of speed of cutting, rate of feed and cutting depth. Table 3 determines the group statics values. From Table 2 the average and SD value of MRR for flood cooling is 0.6690 and 0.11323 which is more efficient compared to hard machining. The result of the independent T test sample is depicted in Table 4. From the tabulation it is determined that there is a significance among the groups, as $P= 0.03$ ($P<0.05$). The bar chart in Fig. 4 shows the correlation between hard machining and flood cooling approaches, which shows that flood cooling has better mean accuracy and standard deviation than the dry hard machining.

DISCUSSION

Results obtained from hard machining and flood cooling of 42CrMo4 using PCD and CBN inserts show that the performance of both the tools are good enough and the better results are obtained for flood cooling rather than hard cooling (Senthilkumar, Tamizharasan, and Anandakrishnan 2014b). In flood cooling effective heat transfer occurs as the interface between tool and workpiece and tool and chip whereas in dry machining heat transfer takes place only with the atmosphere air. Due to this higher material is removed from the workpiece (Gajrani et al. 2019). The significance value obtained for this study is lower ($p=0.03$) than the considered ($p<0.05$) as the analysis is performed with 95% confidence interval. Hence it is observed that a significant variance exists between the experimental and control group. The Fischer value obtained for the study is 11.364.

Apart from this cooling method, the parameters that mainly affect the MRR are cutting depth, rate of feed and speed of cutting (Senthilkumar and Tamizharasan 2014). Due to the high hardness of die steel, low grade cutting tools will produce higher tool wear and poor surface finish even though higher MRR is achieved. For reduced surface damage the cutting depth and rate of feed has to be optimum (Senthilkumar, Sudha, and Muthukumar 2015). The result obtained from this study matches with the results obtained by previous researchers (Tamizharasan et al. 2019) and no opposing findings have been recorded.

From the Bar chart (Fig. 4), it is identified that the flood cooling process has a maximum material removal rate with advanced inserts. Hard machining is comparatively low in MRR with varying machining factors viz., speed of cutting, rate of feed and machining depth. Material removal rate is dependent on these parameters. Increase in these parameters affects material removal rate.

CONCLUSION

In this work, performance of two different cutting tool inserts such as PCD and CBN are compared along with the impact of novel dry machining with conventional flood cooling system during turning tool steel 42CrMo4. The performance measure considered in this study is the amount of material removed, MRR. 18 samples are considered for each insert and it is found that performance of CBN is higher than PCD tool. Also due to higher heat removal through flood cooling higher MRR is observed. Cooling the interfaces such as tool-chip and tool-workpiece effectively improves the performance of both the inserts.

DECLARATION

The authors declare that there is no conflict of interest.

Authors Contribution

The author VG was involved in data collection, analysis and drafting of the manuscript and author NSK was involved in conceptualization, data validation and critical review of manuscript.

Acknowledgement

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding

We thank the following organizations for providing financial support that enabled us to complete the study.

1. Veekay Process Instruments, Chennai.
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha School of Engineering
5.

REFERENCES

1. Biermann, D., H. Hartmann, I. Terwey, C. Merkel, and D. Kehl. 2013. "Turning of High-Strength Bainitic and Quenched and Tempered Steels." *Procedia CIRP*. https://doi.org/10.1016/j.procir.2013.05.047.
2. Das, Anshuman Patel: Saroj, Tapano Kumar Hotta, and Bibhuti Bhushan Biswal. 2019. "Statistical Analysis of Different Machining Characteristics of EN-24 Alloy Steel during Dry Hard Turning with Multilayer Coated Cermet Inserts." *Measurement* 134 (February): 123–41.
3. Dinesh, S., A. Godwin Antony, K. Rajaguru, and V. Vijayan. 2016. "Investigation and Prediction of Material Removal Rate and Surface Roughness in CNC Turning of En24 Alloy Steel." *Asian Journal of Research in Social Sciences and Humanities*. https://doi.org/10.5958/2249-7315.2016.00654.7.
4. Gajrani, Kishor Kumar, P. S. Suvin, Satish Vasu Kailas, and Mamilla Ravi Sankar. 2019. "Hard Machining Performance of Indigenously Developed Green Cutting Fluid Using Flood Cooling and Minimum Quantity Cutting Fluid." *Journal of Cleaner Production* 206 (January): 108–23.
5. Jain, Ravindra Kumar, Sridhar Prem Kumar, and W. S. Manjula. 2014. "Comparison of Intrusion Effects on Maxillary Incisors among Mini Implant Anchorage, J-Hook Headgear and Utility Arch." *Journal of Clinical and Diagnostic Research: JCDR* 8 (7): ZC21–24.
6. Johansson, Daniel, Andrew Hrechuk, Volodymyr Bushlya, Malin Mårtensson, Antionette Can, and Jan-Eric Ståhl. 2019. "Small Scale Testing of PCD and WC-Co Tooling in Rock Cutting Using Longitudinal Turning." *Wear: An International Journal on the Science and Technology of Friction Lubrication and Wear* 426-427 (April): 1515–22.

7. Johnson, Jayapriya, Ganesh Lakshmanan, Biruntha M, Vidhyavathi R M, Kohila Kalimuthu, and Durairaj Sekar. 2020. "Computational Identification of MiRNA-7110 from Pulmonary Arterial Hypertension (PAH) ESTs: A New microRNA That Links Diabetes and PAH." *Hypertension Research: Official Journal of the Japanese Society of Hypertension* 43 (4): 360–62.
8. Keerthana, B., and M. S. Thenmozhi. 2016. "Occurrence of Foramen of Huschke and Its Clinical Significance." *Journal of Advanced Pharmaceutical Technology & Research* 9 (11): 1835.
9. Kim, Dong Min, Ineon Lee, Sun Keel Kim, Bo Hyun Kim, and Hyung Wook Park. 2016. "Influence of a Micropatterned Insert on Characteristics of the Tool–workpiece Interface in a Hard Turning Process." *Journal of Materials Processing Technology* 229 (March): 160–71.
10. Krishna, R. Nivesh, and K. Yuvaraj Babu. 2016. "Estimation of Stature from Physiognomic Facial Length and Morphological Facial Length." *Journal of Advanced Pharmaceutical Technology & Research* 9 (11): 2071.
11. Menon, Aniruddh, and M. S. Thenmozhi. 2016. "Correlation between Thyroid Function and Obesity." *Journal of Advanced Pharmaceutical Technology & Research* 9 (10): 1568.
12. Samuel, Melvin S., Jayanta Bhattacharya, Sankalp Raj, Needhidasan Santhanam, Hemant Singh, and N. D. Pradeep Singh. 2019. "Efficient Removal of Chromium(VI) from Aqueous Solution Using Chitosan Grafted Graphene Oxide (CS-GO) Nanocomposite." *International Journal of Biological Macromolecules* 121 (January): 285–92.
13. Senthilkumar, N., V. Selvakumar, and T. Tamizharasan. 2016. "Optimization and Performance Analysis of Uncoated and Coated Carbide Inserts during Hard Turning AISI D2 Steel Using Hybrid GRA-PCA Technique." *Applied Mechanics and Materials*. https://doi.org/10.4028/www.scientific.net/amm.852.151.
14. Senthilkumar, N., J. Sudha, and V. Muthukumar. 2015. "A Grey-Fuzzy Approach for Optimizing Machining Parameters and the Approach Angle in Turning AISI 1045 Steel." https://www.academia.edu/download/58220051/APEM10-4_195-208.pdf.
15. Senthilkumar, N., and T. Tamizharasan. 2014. "Application of Response Surface Methodology and Firefly Algorithm for Optimizing Multiple Responses in Turning AISI 1045 Steel." *Arabian Journal for Science and Engineering*. https://link.springer.com/article/10.1007/s13369-014-1320-3.
16. Senthilkumar, N., and T. Tamizharasan. 2015. "Flank Wear and Surface Roughness Prediction in Hard Turning via Artificial Neural Network and Multiple Regressions." *Australian Journal of Mechanical Engineering*. https://doi.org/10.7158/m13-045.2015.13.1.
17. Senthilkumar, N., T. Tamizharasan, and V. Anandakrishnan. 2014a. "An Hybrid Taguchi-Grey Relational Technique and Cuckoo Search Algorithm for Multi-Criteria Optimization in Hard Turning of AISI D3 Steel." *Journal of Advanced Engineering Research* 1 (1): 16–31.
18. Senthilkumar, N., T. Tamizharasan, and V. Anandakrishnan. 2014b. "Experimental Investigation and Performance Analysis of Cemented Carbide Inserts of Different Geometries Using Taguchi Based Grey Relational Analysis." *Measurement*. https://www.sciencedirect.com/science/article/pii/S0263224114004059.
19. Sriram, Nirisha, Thenmozhi, and Samrithi Yuvaraj. 2015. "Effects of Mobile Phone Radiation on Brain: A Questionnaire Based Study." *Journal of Advanced Pharmaceutical Technology & Research* 8 (7): 867.
20. Subashri, A., and M. S. Thenmozhi. 2016. "Occipital Emissary Foramina in Human Adult Skull and Their Clinical Implications." *Journal of Advanced Pharmaceutical Technology & Research* 9 (6): 716.
21. Sudharsan, S. 2020. "Experimental Investigation of the Effect of Process Parameters on Material Removal Rate and Surface Finish." *International Journal of Advanced Research in Science, Communication and Technology*. https://doi.org/10.48175/ijarsct-650.
22. Tamizharasan, T., and N. Senthilkumar. 2012. "Analysis of Surface Roughness and Material Removal Rate in Turning Using Taguchi's Technique." In , 231–36. I. EGS Pillay Engineering College.
23. Tamizharasan, T., N. Senthilkumar, V. Selvakumar, and S. Dinesh. 2019. "Taguchi's Methodology of Optimizing Turning Parameters over Chip Thickness Ratio in Machining P/M AMMC." *SN Applied Sciences*. https://doi.org/10.1007/s42452-019-0170-8.
24. Thejeswar, E. P., and M. S. Thenmozhi. 2015. "Educational Research-iPad System vs Textbook System." *Journal of Advanced Pharmaceutical Technology & Research* 8 (8): 1158.
25. Venu, Harish, Lingesan Subramani, and V. Dhana Raju. 2019. "Emission Reduction in a DI Diesel Engine Using Exhaust Gas Recirculation (EGR) of Palm Biodiesel Blended with TiO2 Nano

Additives." *Renewable Energy* 140 (September): 245–63.
26. Xu, Qingzhong, Jun Zhao, and Xing Ai. 2017. "Cutting Performance of Tools Made of Different Materials in the Machining of 42CrMo4 High-Strength Steel: A Comparative Study." *International Journal of Advanced Manufacturing Technology* 93 (5): 2061–69.

Tables and figures

Table 1. Workpiece chemical constituents In terms of weight % for 42CrMo4

Elements	**Carbon**	**Silicon**	**Manganese**
Weight %	0.38-0.45	0,10-0.40	0.60-0.90

Table 2. Considered groups with obtained MRR for hard machining and flood cooling techniques

Exp. No	**Hard machining - MRR (g/min)**		**Flood Cooling - MRR (g/min)**	
	PCD	**CBN**	**PCD**	**CBN**
1	18.32	40.05	20.37	75.54
2	33.38	45.86	24.91	78.65
3	38.63	52.91	30.55	84.33
4	45.86	59.14	35.55	87.23
5	52.91	63.75	40.03	91.42
6	22.71	68.54	47.73	96.16
7	28.65	71.17	59.58	97.23
8	32.38	78.34	64.17	100.87
9	36.73	82.43	69.67	102.85

Table 3. Group statistics obtained during comparison of hard machining and flood cooling along with standard deviation, mean and values of standard error.

Machining Technique	N	Mean	Standard Deviation	Standard Error
Hard machining	20	48.4311	18.97603	4.47269
Flood cooling	20	67.0467	27.80566	6.55386

Table 4. Outcomes of independent sample T-test shows significance variance among hard machining and flood cooling techniques as p<0.05.

Hypothesis	F	Significance	t	Standard Error Difference
Equal variances assumed	4.161	.0.049	2.346	7.93461
Equal variances not assumed			2.346	7.93461

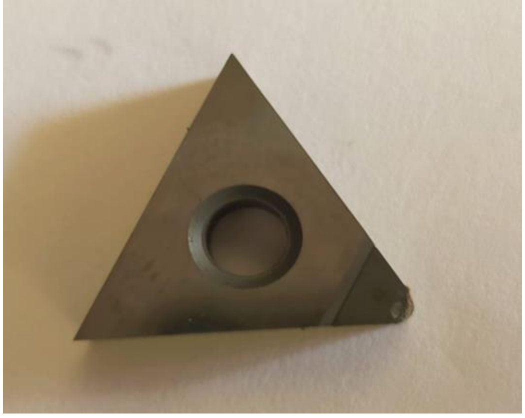

Fig. 1. Polycrystalline Diamond insert - TNMG 160408 EN - M42 - Cutting edge length 16.5 mm; Fixing hole diameter -3.81 mm; Insert width 4.76 mm; Cutting edge position code E - Rounded; Insert hand N - Neutral; Corner radius 0.8 mm.

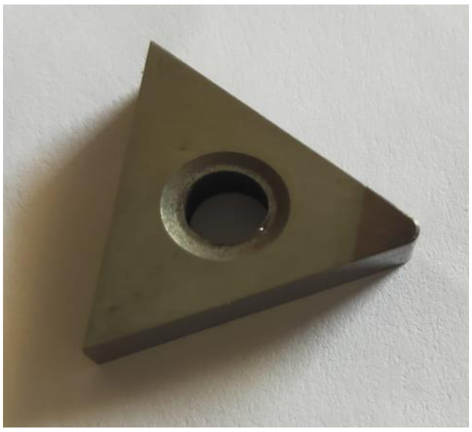

Fig. 2. CBN insert TNMG 160408 having 3.81 mm diameter of fixing hole with 4.76 mm thickness and 0.8 mm corner radius and 16.5 mm length of cutting edge.

Fig. 3. CNC Machining Centre - Mega Jobber.

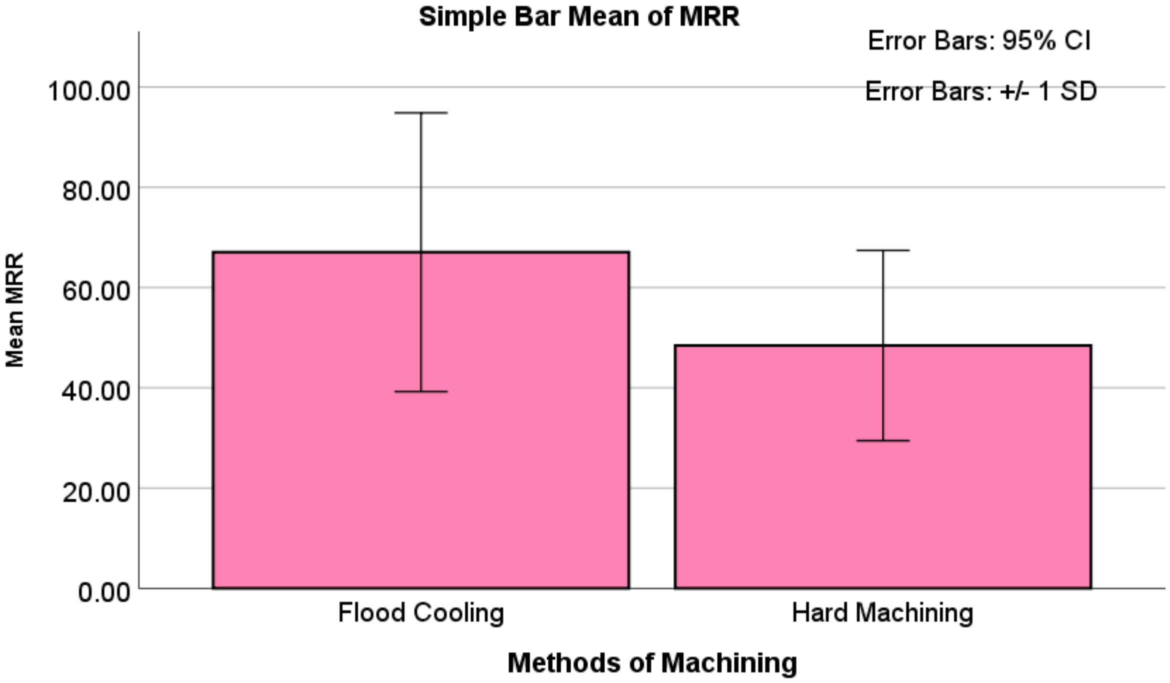

Fig. 4. Comparison of hard machining and flood cooling approaches in perspective of mean precision The average precision of flood cooling is higher than the hard machining . MRR mean detection precios of ±1SD