International Journal of Engineering Computational Research and Technology

Journal home page: www.ijecrt.org

ISSN (Online): 2456-9852 Volume 4, Issue 1, June 2019

Machinability Studies of Nickel Based Super Alloys on Abrasive Waterjet Machining

S. Saikumar[a], J. Raghavender[b], K. Koushik[c], M. M. Gopala Krishna[d], Dipesh Popli[e]

[a-e] *Department of Mechanical Engineering, Bharat Institute of Engineering and Technology, Hyderabad, Telangana-501510, INDIA*

[*] Corresponding author:
E-mail address: drjssoni@yahoo.com (S. Saikumar).

ABSTRACT

CMSX-4 is an ultra - high strength, single crystal advanced nickel based superalloy. It is a directionally solidified single crystal superalloy. This second generation rhenium-containing, nickel-base single crystal alloy is capable of higher peak temperature/stress operation of at least 1163°C. CMSX-4 is extremely difficult to machine by using conventional machining processes. In this project work, we have used the OMAX 55100 Jet Machining Center for cutting the CMSX-4 specimen samples of gas turbine blades. Five different levels of quality were employed ranging from quality 1 to quality 5. It was observed that as the cutting quality increases the MRR decreases. An inverse proportionality relation was observed between the traverse speed and cutting quality, surface finish

Keywords:
AWJM
CMSX 4
Surface Roughness
SOD
MRR

1. Introduction

The abrasive waterjet machine is an effective technology for processing various materials. In this process the metal removal takes place by impact erosion of high pressure, high velocity of water with high velocity of abrasives on a work piece. The abrasive waterjet offers several advantages over conventional cutting techniques as it environmental friendly and it can cut metals and nonmetals also [1, 3, 4, 8, 9].

Here the CMSX 4 [2] metal is machined on OMAX 55100 Abrasive waterjet machining at Armour Technology Center [ATC], DMRL

2. Experimental work

2.1 Material

CMSX-4 [2, 5, 6, 10], is an advanced Ni based superalloy developed by Cannon Muskegon. Single crystal Ni-based superalloys [7] are developed especially for the most critical elements applied in high temperatures and load conditions. They exhibit excellent creep, oxidation and corrosion resistance and for these reasons are mostly used in aerospace and nuclear industry. The chemical composition is comprised of 68.7% Ni and the rest includes the elements Cr,Co,Mo,Al,Ti,Ta,Hf,Re.

2.2 Composition

Table 1 shows chemical composition of CMSX-4

Table 1. Chemical composition of CMSX-4(wt. %)

Cr	Al	Ti	Mo	W	Ta	Co	Re	Hf	Ni
6.4	5.7	1.0	0.6	6.3	6.5	9.5	2.9	0.1	bal.

2.3 Experimental Observations

The equipment has the constant parameters shown in Table 2:

Table 2. Constant parameters

Orifice diameter	Focusing tube diameter	Water pressure PSI	Abrasive type	Abrasive size
0.2	0.792	37000	garnet	80 mesh

2.4 Input parameters

The input parameters shown in Table 3:

Table 3. Input parameters

Input parameters	Q1	Q2	Q3	Q4	Q5
Surface quality	1	2	3	4	5
Pressure KSI	37	37	37	37	37
SOD mm	0.5	1.0	1.5	2.0	3.0
Flow rate kg/min	0.320	0.320	0.320	0.34	0.34
Traverse speed	176	146.6	66.6	52.8	35.2
Machinability	70.17	70.17	70.17	70.17	70.1

3. Surface finish of Specimen Samples

Surface finish of specimen samples quality wise shown in Fig. 1 to 5.

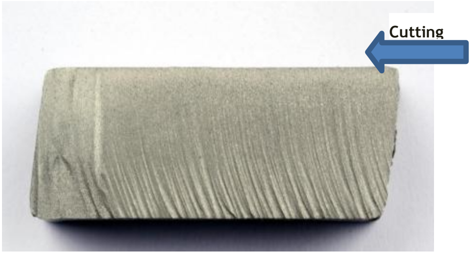

Fig 1. Surface finish of specimen sample quality-1

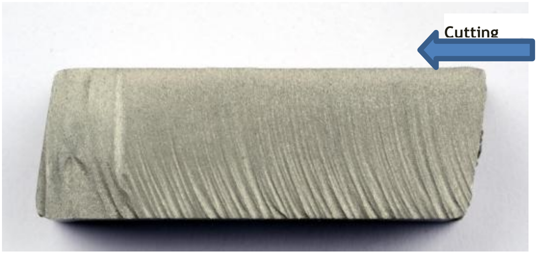

Fig 2. Surface finish of specimen sample quality-2

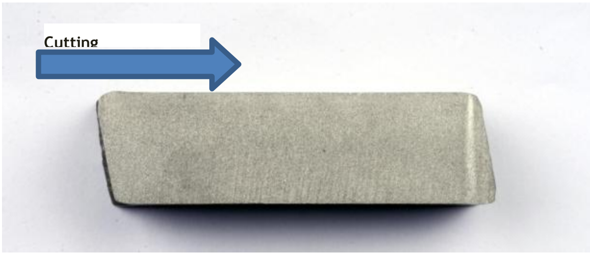

Fig 3. Surface finish of specimen sample quality-3

Fig 4. Surface finish of specimen sample quality-4

Fig 5. Surface finish of specimen sample quality-5

4. Surface Roughness measurement using Taylor Hobson Form TalySurf II

Surface Roughness measurement using Taylor Hobson Form TalySurf II shown in Table 4:

Table 4. Surface Roughness measurement using Taylor Hobson Form TalySurf II

Quality	Surface Roughness
1	3.4316
2	3.0875
3	2.7513
4	2.5536
5	2.4102

5. Results Discussion

Table 5. Experimental Results of proposed system

Quality	Time (sec)	MRR (g/s)	Taper Width(mm)
1	15	0.239	1.3
2	18	0.203	1.3
3	40	0.085	0.9
4	50	0.083	0.74
5	75	0.053	0.6

It was found that, we get the best surface finish for CMSX-4 at quality 5 and the bad surface finish at quality1.As the traverse speed increases, the cutting quality and the surface finish degrades. The MRR increases as the time taken for cutting decreases. With the comparison of the macro structures from the stereoscopic images upto 200 microns, it is found there are several indentation in all the qualities but the quality 4,5 has the least and offers smoother surface. The surface finish was found from Tylor Hobson surface roughness testing machine and the finish for the quality 5 cut was found to be 2.5536 µm.

It was observed that for different qualities of cutting the time taken is changing, from the table 7.1 it is clear that for quality 1 it took less time while with the increase in quality the time for cutting the material is increasing.

For lower quality cut it took less time to cut the material which means the increased traverse speed but it was observed that the MRR is very high for the low-quality cut and material removed is very high for this low-quality material and also the surface finish of the low quality is very low.

It was also observed that it took two passes to finish the cut for quality1 and quality 2 it is because of increased traverse speed. The upper part of cut surface roughness for different quality cuts is varying in from 2-4 µm and when coming to the lower part roughness is very high for quality 1 and quality 2 which is difficult measure with the talysurf and for quality 4 and quality 5 the value of roughness is changing slightly.

6. Conclusion

Abrasive waterjet machining has a very good scope for machining the advance nickel-based superalloys such as CMSX-4. Generally, EDM is used for machining CMSX-4.

AWJM has no heat affected zone and does not alter the properties and microstructure of the work piece. It is much faster and efficient and versatile than the other methods.

We can get the required surface finish by changing the input parameter and choosing the quality required.

High surface quality was obtained with abrasive waterjet cutting by using high pressure and low traverse speeds.
For the higher traverse speed the material removal rate is more and The taper angle formed is increased with the increasing traverse speed.

The irregularities formed at the bottom part the work piece is due to the variation of traverse speed. The number of passes required to cut a work piece decreases with the decrease in the traverse speed.

References

[1] Begic-Hajdarevic, D., Cekic, A., Mehmedovic, M., & Djelmic, A. (2015). Experimental study on surface roughness in abrasive water jet cutting. Procedia Engineering, 100(January), 394–399. https://doi.org/10.1016/j.proeng.2015.01.383

[2] Dubiel, B. T., & Czyrska-Filemonowicz, A. (2010). Microstructural changes during creep of CMSX-4 single crystal Ni base superalloy at 750°C. Journal of Microscopy, 237(3), 364–369. https://doi.org/10.1111/j.1365-2818.2009.03261.x

[3] Elmabrok, O. M., Aziz, A., & Badi, M. (2017). An Implementation of Fuzzy Logic Technique to Predict the Material Removal Rate in Abrasive Water Jet Machining Process. Libyan Journal for Engineering Research (LyJER), 1(2), 30–33.

[4] Gupta, V., Pandey, P. M., Garg, M. P., Khanna, R., & Batra, N. K. (2014). Minimization of Kerf Taper Angle and Kerf Width Using Taguchi's Method in Abrasive Water Jet Machining of Marble. Procedia Materials Science, 6(Icmpc), 140–149. https://doi.org/10.1016/j.mspro.2014.07.017

[5] Harris, K., & Wahl, J. B. (2004). Improved Single Crystal Superalloys, CMSX-4 (SLS)[La+Y] and CMSX-486. TMS (The Minerals, Metals & Materials Society), 45–52. https://doi.org/10.7449/2004/superalloys_2004_45_52

[6] Okazaki, M., & Sakaguchi, M. (2008). Microstructural Degradation of Cmsx-4: Kinetics and Effect on Mechanical Properties, (January 2016). https://doi.org/10.7449/2008/Superalloys

[7] Popli, D., & Gupta, M. (2018). Investigation of the Circularity and Conicity of Super Alloy during Rotary Ultrasonic Machining. Iranian Journal of Science and Technology, Transactions of Mechanical Engineering. https://doi.org/10.1007/s40997-018-0197-2

[8] Qiang, C. H., & Guo, C. W. (2018). Abrasive slurry jet cutting model based on fuzzy relations. IOP Conference Series: Materials Science and Engineering, 283(1). https://doi.org/10.1088/1757-899X/283/1/012025

[9] Vundavilli, P. R., Parappagoudar, M. B., Kodali, S. P., & Benguluri, S. (2012). Fuzzy logic-based expert system for prediction of depth of cut in abrasive water jet machining process. Knowledge-Based Systems, 27, 456–464. https://doi.org/10.1016/j.knosys.2011.10.002

[10] Wahl, J. B., & Harris, K. (1984). Improved 3 rd Generation Single Crystal Superalloy CMSX-4® Plus (SLS)-a study of evolutionary alloy development. Note, 1. Retrieved from https://cannonmuskegon.com/wp-content/uploads/2018/08/Improved-3rd-Generation-Single-Crystal-Superalloy-CMSX-4®-Plus-SLS.pdf