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EXPERIMENTAL INVESTIGATION OF TEMPERATURE DISTRIBUTION AND SURFACE ROUGHNESS FOR CUTTING ALUMINIUM-19000 AND STAINLESS STEEL 304 USING PLASMA ARC CUTTING

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ABSTRACT

The comparative analysis of temperature distribution and surface roughness between Aluminium-19000 and stainless steel 304 were done using plasma arc cutting process under identical set of condition i.e. current, voltage, velocity of cut and gas pressure. The variation of temperature along the cutting length were recorded and analyzed for the rectangular profile of the specimen using thermal imaging camera and IR spectroscopy. The surface roughness for both the specimen was measured using surface roughness tester and comparative analysis was done. The maximum and minimum temperature during cutting for Aluminium-19000 was >650°C and 209°C respectively and for stainless steel it was found to be 614°C and <140°C. The various parameters affecting temperature distribution are the emissivity and conductivity of the material and also the convection and radiation during the process. The surface roughness was affected by gas pressure and velocity of cut. The rapid cooling during the process affect the grain structure of the material and due to this surface topography is also affected by this that lead to affect the surface roughness of the materials.

I. INTRODUCTION

Plasma arc cutting (PAC) is a non-conventional machining process which is capable of machining different electrically conducting materials. Manganese steel, Stainless steel, titanium alloys, magnesium, copper, aluminum and its alloys and cast iron can be processed. The plasma process for cutting was developed approximately thirty- five years ago, for metals which were difficult to be machine through conventional machining processes. It uses a high-energy and high temperature stream of dissociated, ionized gas, known as plasma, as the heat source [1]. Plasma arc cutting (PAC) is a very important thermal cutting process and has been used successfully in the cutting of stainless steel, high hardness metals, high melting point metals, and other difficult to machine alloys [2-3]. The plasma melts the material being cut and swiftly moves blowing molten metal away from the cutting zone [4]. Plasma arc current, torch geometry, gas type, flow rate, and cutting speed factors have important affects on the cutting quality.

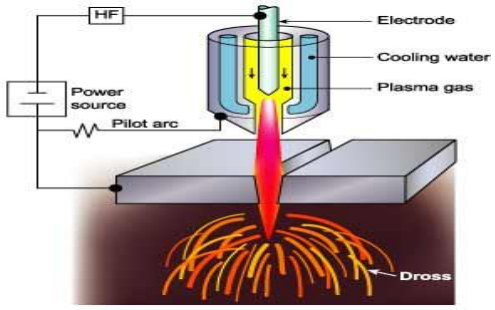


Fig. 1: Schematic diagram of Plasma arc cutting

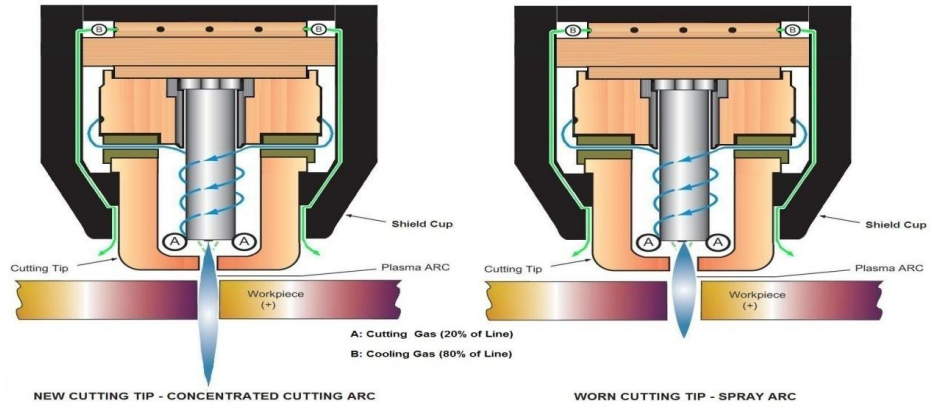


Fig. 2: Difference in arc blow between new cutting tip and worn cutting tip

The materials chosen for the present study are Aluminium-19000 and Stainless steel 304 because of their uses and applications in the various fields. Stainless steel 304 is not a reactive metal and behaves like an inert material so it is widely used in medical field like in the manufacturing of surgical tools. Austenitic stainless steel 304 also used in pipes of chemical plants and other applications that may subject to the conditions of cyclic load [5].

Table 1: Properties of Stainless steel grade 304 and Aluminium-19000

Properties	Stainless steel grade 304	Aluminium-19000
Brinell hardness	123	105
Vicker hardness	129	95
Ultimate tensile strength	505 MPa	290 MPa
Yield strength	215 MPa	148 MPa
Elongation at break	70%	43%
Modulus of elasticity	195 GPa	120 GPa
Poisson's ratio	0.29	0.35
Shear modulus	86 GPa	42 GPa
Electrical resistivity	7.2×10^{-5}	5.4×10^{-5}
Thermal conductivity	16.2 W/m-K	29 W/m-K
Specific heat capacity	0.5 J/Kg-°C	0.35J/Kg-°C
Melting point	1400°C-1455°C	680°C-740°C
Coefficient of linear expansion	17.3 µm/m-°C	24.5µm/m-°C

Earlier the researchers were studied on plasma arc cutting and did various investigations on both materials i.e. Aluminium-19000 and Stainless steel 304. Dalvir Singh et al. [6-7] studied numerically and mapped with infrared during plasma arc cutting of mild steel and also comparison was done for temperature measurement in plasma cutting through infra red imaging and FEM. K. Salonitis et al. [8] investigated the plasma arc cutting process experimentally. Comparative study between metal water jet cutting with laser and plasma cutting was done by Daniel Krajcarz et al. [9]. R. Bini [10] studied the feature of kerf generated by a 200 A high tolerance plasma arc cutting systm experimentally. E. Gariboldi et al. [11] studied about the high to;erance plasma arc cutting of commercially pure titanium. Milan Kumar Das et al. [12] optimized the process parameter during plasma arc cutting of EN31 steel alloy based on MRR and multiple surface roughness characteristics using grey relational analysis. Subbarao Chamarthi et al. [13] investigated analytically about the plasma arc cutting parameters on the unevenness surface of Hardox-400 material.

In the present experimental study, the temperature distribution during the plasma arc cutting of these two materials and the surface roughness of the materials were studied and compared under identical set of constant parametric conditions i.e. current, voltage, velocity of cut and gas pressure.

II. EXPERIMENTAL PROCEDURE

Fig. 3: Experimental setup used for the present study: An automatic profile cutter

The two material sheets were cut using an automatic profile cutter by generating plasma arc.

Cutting of Aluminium-19000 & stainless steel grade 304:

Fig. 4: Aluminium-19000 workpiece after cutting

Fig. 5: Stainless steel 304 workpiece after cutting

Table 2: Parameters used during the cutting process

PARAMETERS	STAINLESS STEEL GRADE 304	ALUMINIUM GRADE 19000
Dimension of workpiece	15.5x10.2x1.2 (cm)	14.8x9.9X0.9 (cm)
Emissivity of material	0.85	0.20
Current during cutting	45 Amp	45 Amp
Gas pressure	10 kgf/cm2	10 kgf/cm2
Time taken to cut	2min 14 sec	2min 55sec
Hence velocity of cut	0.20cm/sec	0.15cm/sec

III. RESULT

The surface roughnesses of two materials were found as given in Table 3.

Table 3: Average surface roughness value for Stainless steel 304 and Aluminium-19000

Material Type	Ra Value(micro meter)
STAINLESS STEEL GRADE 304	12.75
ALUMINIUM GRADE 19000	18.45

The image was taken through thermal imaging camera and was shown in Fig. 6, Fig. 7, Fig. 8 and Fig. 9. And corresponding graph were shown.

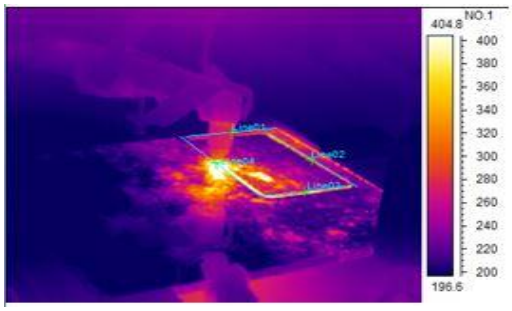
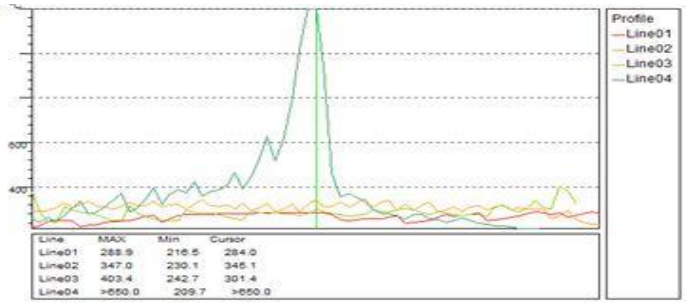


Fig. 6: Aluminium-19000 during cutting



Graph 1: Maximum and minimum temperature at all the four edges

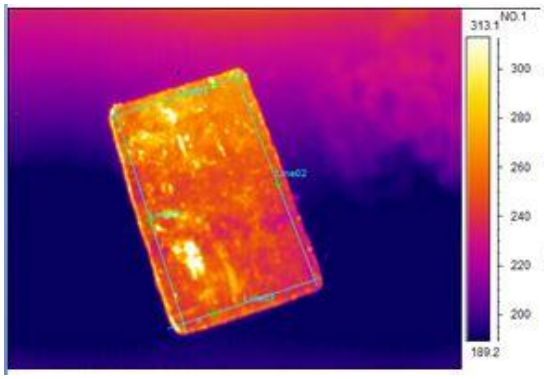
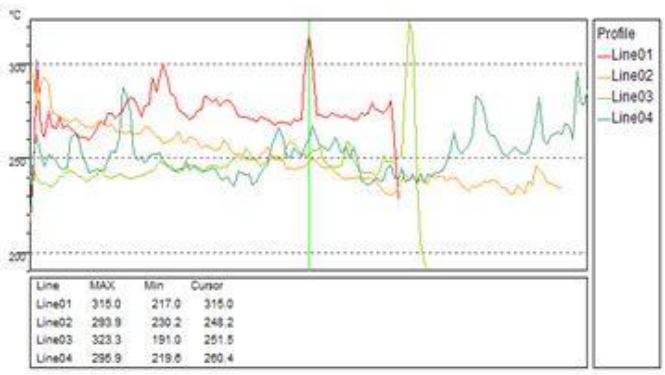


Fig. 7: Aluminium-19000 after cutting



Graph 2: maximum and minimum teperature at the edges

The maximum and minimum temperaature during cutting was found to be >650°C and 209°C at line 04 respectively and afetr cutting these were 315°C and 217°C respectively at line 01 which is due to high convection rate because of large surface area at line 04 edge.

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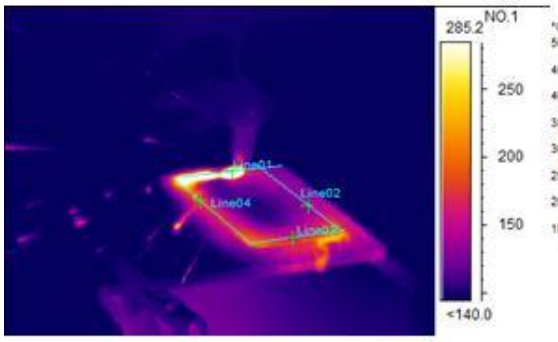
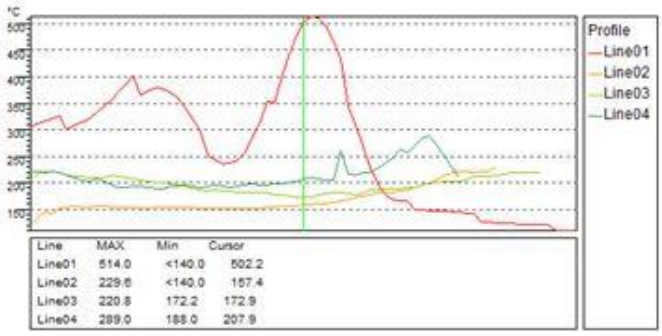


Fig. 8: Stainless steel 304 during cutting



Graph 3: Maximum and minimum temperature at all edges

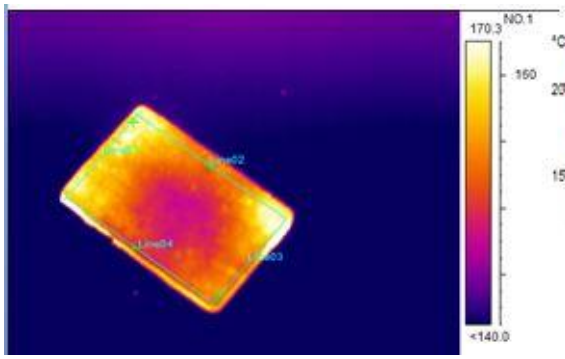
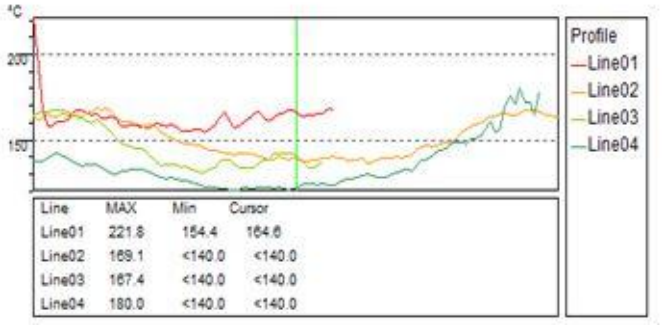


Fig. 9: Stainless steel 304 after cutting



Graph 4: Maximum and minimum temperature at all edges

The maximum and minimum temperaature during cutting was found to be 614°C and <140°C at line 01 respectively and afetr cutting these were 221.8°C and <140°C respectively at line 01 that means the convection rate for line 01 was very high initially and then it tends to retain its temperature constant.

IV. CONCLUSION

1) Hence we observed that surface roughness of Stainless Steel Grade 304 is better than ALUMINIUM GRADE 19000 under performed condition.
2) Time taken to cut Stainless Steel Grade 304 is less than ALUMINIUM GRADE 19000 under performed condition.
3) The maximum and minimum temperature for stainless steel was lower than the respective temperature for Aluminium-19000 material.

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