DETERMINATION OF WELDING PARAMETERS IN HARD SURFACING PROCESS OF AISI 316 STAINLESS STEEL SUBSTRATE WITH FUSED TUNGSTEN CARBIDE IRON-BASED TUBULAR WIRES

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Key words: *hard surfacing process, CNC welding, 3D scanning, tungsten carbide, wear resistance*

Abstract:

This study investigates welding parameters for hard surfacing process of AISI 316 stainless steel substrate with open arc iron-based tubular wire filled with fused tungsten carbide. The goal is to find minimum welding voltage and current for depositing process to avoid greater deformations of the substrate. The only limiting factor was that the thickness of the deposited layer must be 2 mm above the substrate. After the deposition process, we first scanned the surface to immediately eliminate substrates that did not meet the limiting factor.

1. Introduction:

Wear is the predominant factor that controls the life of any machine part. Metal parts often fail their intended use not because they fracture, but because they wear, which causes them to lose dimensions and functionality. Most typical types of wear are – Abrasion, Corrosion, Impact, Heat, Metallic (metal to metal), etc. Recently, researchers have shown an increased interest in surface coatings application to improve wear resistance which can prolong the life of components [1, 2]. Hardfacing (also known as hard surfacing) is the application of buildup of deposited of specialized alloys using welding processes to resist abrasion, corrosion, high temperature and/or impact. The component's service life in abrasive environment can be prolonged by hardfacing deposit, especially on the parts that erewere exposed to production process [3-6]. These alloys can be deposited on the entire surface or merely at the point of a part subjected to wear. The material's technology has experienced significant progress over the last years, especially in terms of surface coatings.

The quality of surface weld depends on various factors like process parameters influencing bead geometry, bead quality as well as mechanical-metallurgical characteristics of the surfaced metal includes the welding current, voltage, wire feed rate, electrode traverse speed, nozzle to plate distance, gas flow rate, etc.

Our goal with this research is to find optimal welding parameters for hard surfacing of AISI 316 stainless steel substrate. When polished, the thickness of welded material needed to be 2 mm above the substrate surface. For hard surfacing, we used DURMAT OA wire. DURMAT OA is an open arc iron-based tubular wire filled with 60% of fused tungsten carbide for the semi-automatic application. This iron-based tubular wire filled with fused tungsten carbide is used for hard facing and repairing tools and machine parts that are exposed to wear in mining, excavation, earth moving, tunneling shields, road construction, well drilling and deep drilling applications.

Physical characteristics of DURMAT OA:

Hardness:	Weld metal:	1st layer approx. 64 – 66 HRC 2nd layer approx. 66 – 68 HRC
	Carbide:	Typically 60% of fused tungsten carbides of approx. 2360 $HV_{0,1}$

Welding recommendations:

$\emptyset\ mm$	Amps	Voltage
1.2	130 – 600 A	24 – 26V

2. Experimental procedure

For hard surfacing process, we designed welding machine with CNC control so we can program the machine to weld on any trajectory as visible on Fig. 1. with fully digitized microprocessor-controlled inverter power source Fronius TransSynergic 4000. For CNC controller, we used ArtSoft - Mach3 software.

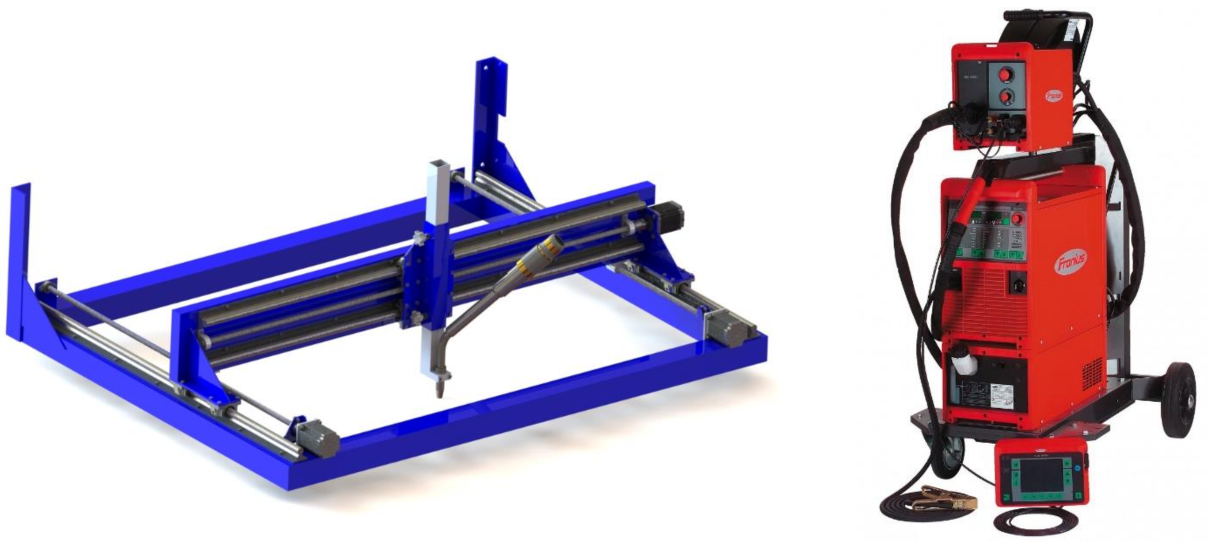

Fig. 1. CNC Welding Table and Power Source TransSynergic 4000

For substrate, we used AISI 316 stainless steel of dimensions $130mm$ x $100mm$ x $10mm$. Welding was carried out in one passage through the serpentine path as shown in Fig. 2 with deposited area of $50mm$ x $50mm$. Torch speed was kept constant for all substrates at $300\ mm/min$ and perpendicular to substrate surface. Also, torch distance from substrate surface was 15 mm for all substrates. For shielding gas, we used Messer Inoxline X2. Welding time for every substrate was 2 minutes and 40 seconds. We hard surfaced six substrates, all with different welding parameters presented in Table 1. The substrate was not preheated.

Table 1 Welding parameters

Substrate No.	Gas flow $[l/min]$	Torch speed $[mm/min]$	Wire feed rate $[m/min]$	Voltage $[V]$	Welding wire
1	10	300	2	17	Durmat OA 1.2
2	10	300	2	19	Durmat OA 1.2
3	10	300	2	21	Durmat OA 1.2
4	10	300	4	17	Durmat OA 1.2
5	10	300	4	19	Durmat OA 1.2
6	10	300	4	21	Durmat OA 1.2

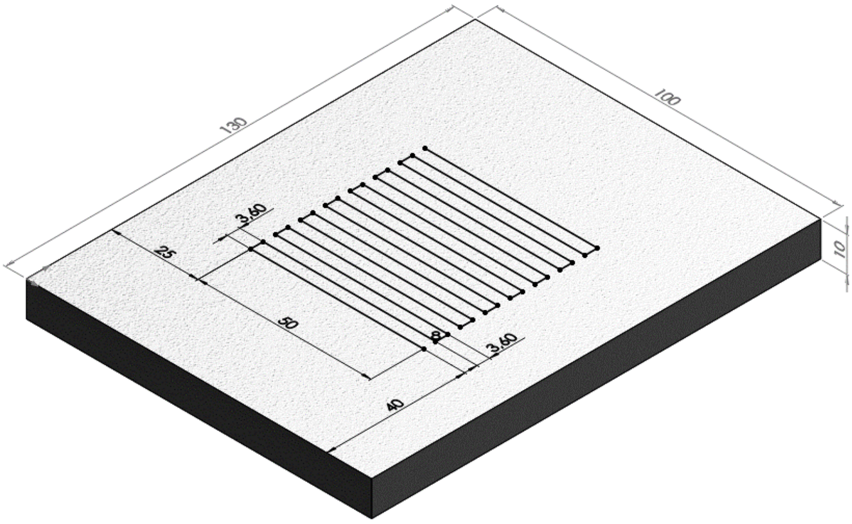

Fig. 1 AISI 316 stainless steel substrate with serpentine welding path

Our goal was to keep welding voltage and current as low as possible to avoid deformations of substrate because of heating during the welding process. Before and after welding process we weight substrates and by doing so we measured deposited material.

We started with welding voltage of 17 V with wire feed rate 2 m/min (Fig. 3a). Between two lines of welding path, appeared gaps due to low wire feed rate and small welding voltage. By increasing welding voltage to 19 V, the final result was a bit better but there was still gaps between two welding lines (Fig. 3.b).

Fig. 2 Welded at: a)17V b)19V c)21V

Fig. 3.c) shows third attempt to weld with wire feed rate at 2 m/min with 21 V and in this case appeared arc breaking because of low wire feed rate and high voltage, and lots of welding spatters appeared. After that, we increased wire feed rate to $4m/min$, and hard surfaced three more substrate with welding voltage $17V$, $19V$ and $21V$ separately as visible at Fig. 4.

Fig. 3 Welded at: a)17V b)19V c)21V

3. Results and Discussion from Current Research

Before grinding and polishing process, we needed to be sure that our hard surfaced substrates satisfy the main requirement of 2*mm* thickness above substrate surface, so we scan them with 3D scanner ATOS Triple Scan. ATOS Triple Scan produces a high accuracy and improved measurement of shiny surface, complete data on complex components with deep pockets or fine edges such as turbine blades, reducing the number of individual scans and resulting in a simple handling.

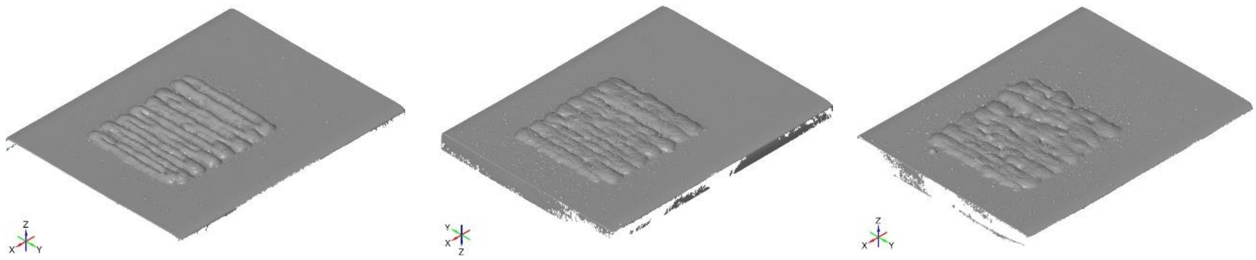

Fig. 4 Scanned surfaces deposited with wire feed rate 2m/mm

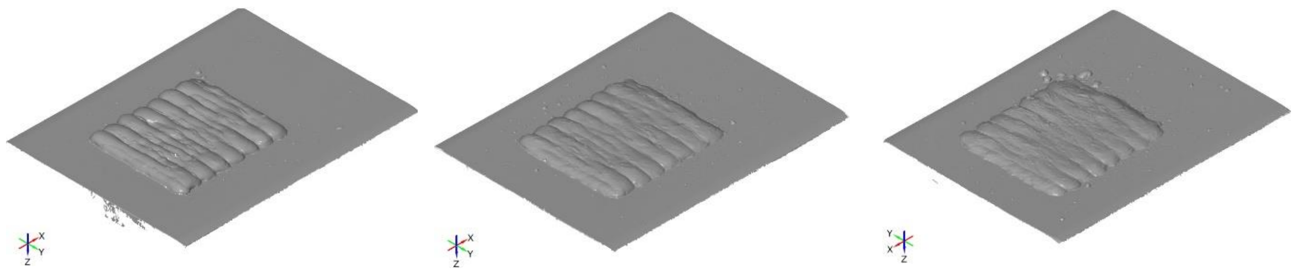

Fig. 5Scanned surfaces deposited with wire feed rate 4m/mm

Processing of scanned samples was performed in GOM inspect software. GOM Inspect is software packages for the analysis of 3D measuring data for quality control, product development, and production. The GOM software is used to evaluate 3D measuring data derived from GOM systems, 3D scanners, laser scanners, CTs, CMMs and other sources.

For nominal elements in GOM inspect we used CAD model as per Fig. 2. and did a surface comparison with actual 3D scans as visible on Fig. 7.

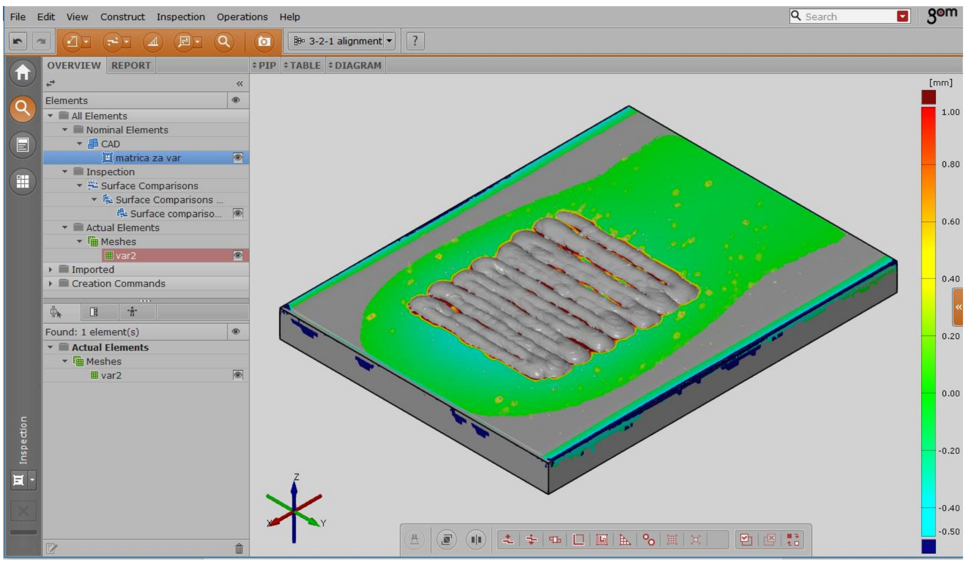

Fig. 6 3D scan analysis in GOM inspect software

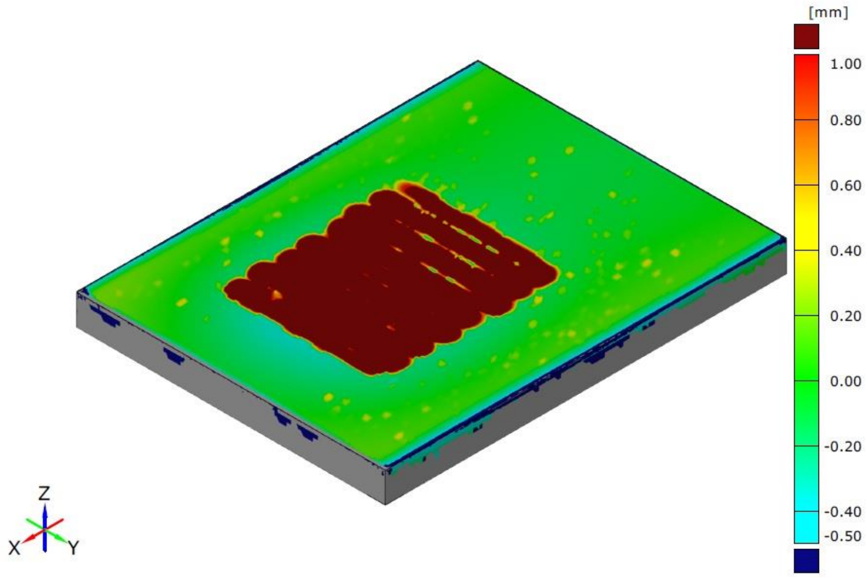

Fig. 7 Scanned surface deposited with welding parameters of wire feed rate 2m/min and 17V

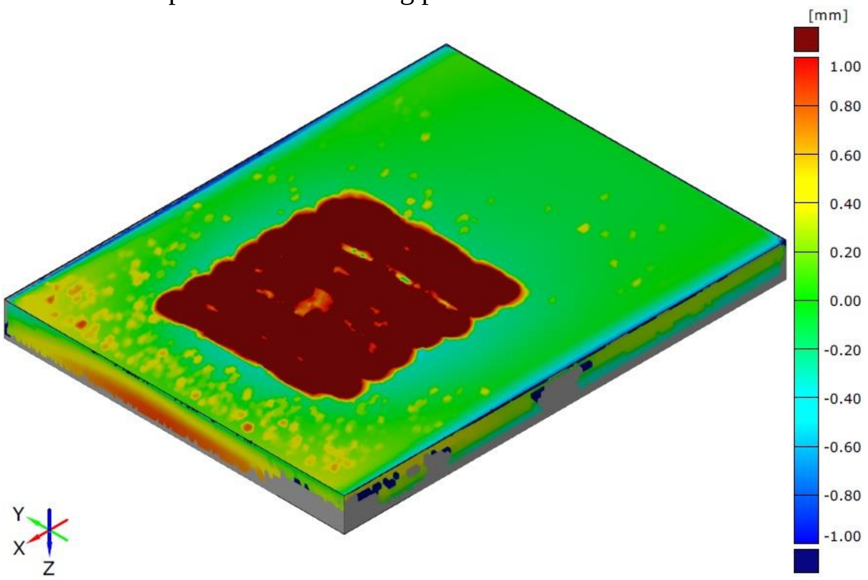

Fig. 8 Scanned surface deposited with welding parameters of wire feed rate 2m/min and 19V

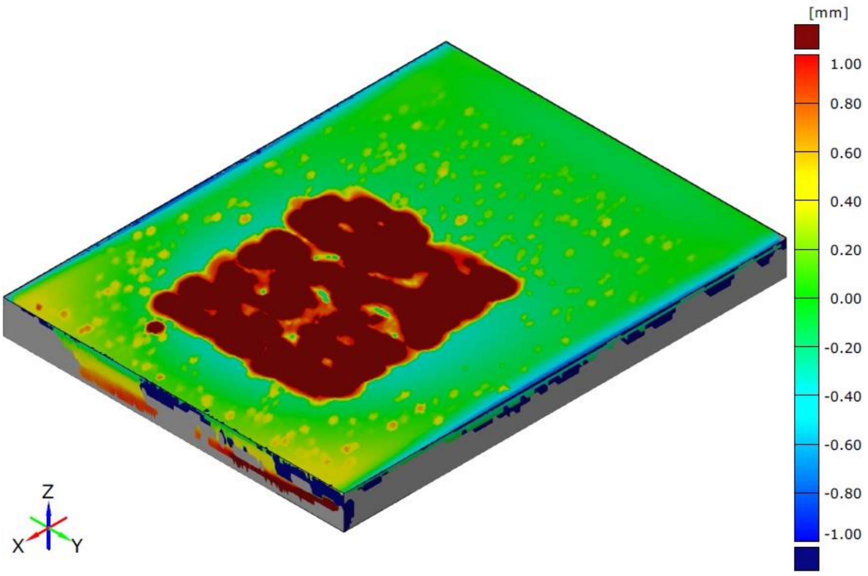

Fig. 9 Scanned surface deposited with welding parameters of wire feed rate 2m/min and 21V

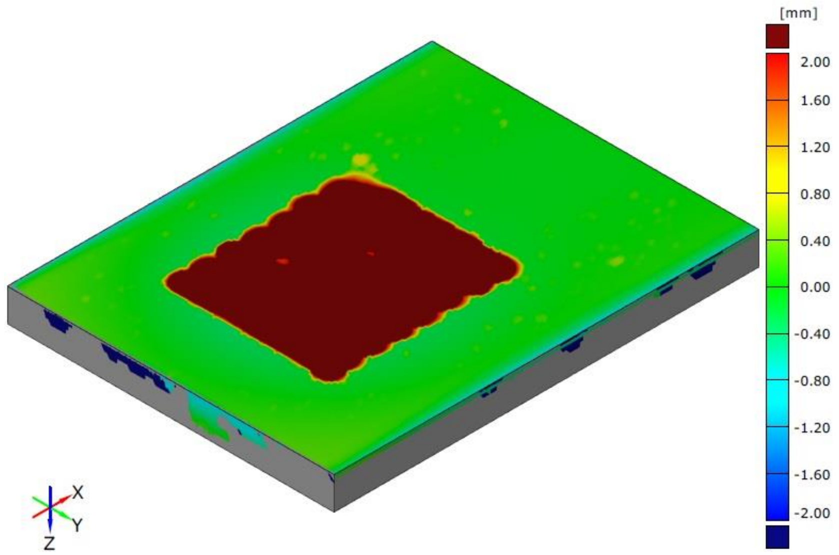

Fig. 10 Scanned surface deposited with welding parameters of wire feed rate 4m/min and 17V

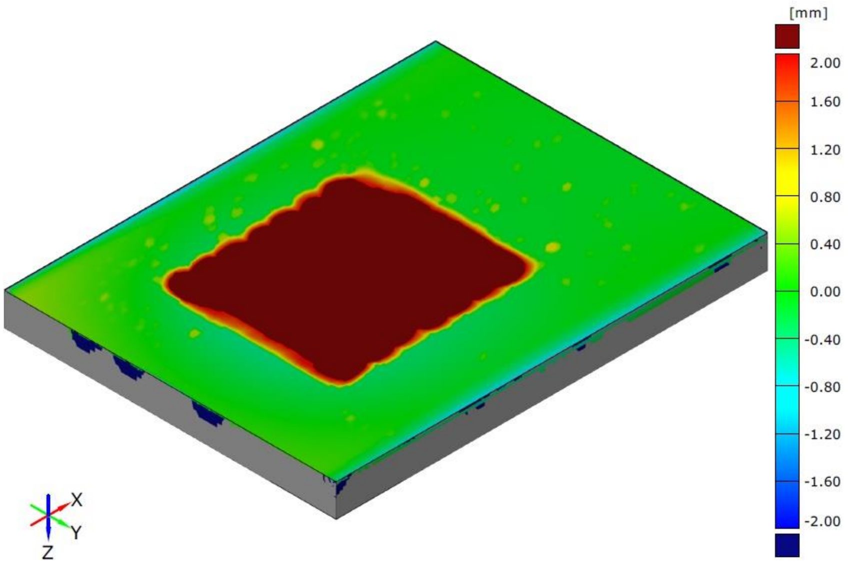

Fig. 11 Scanned surface deposited with welding parameters of wire feed rate 4m/min and 19V

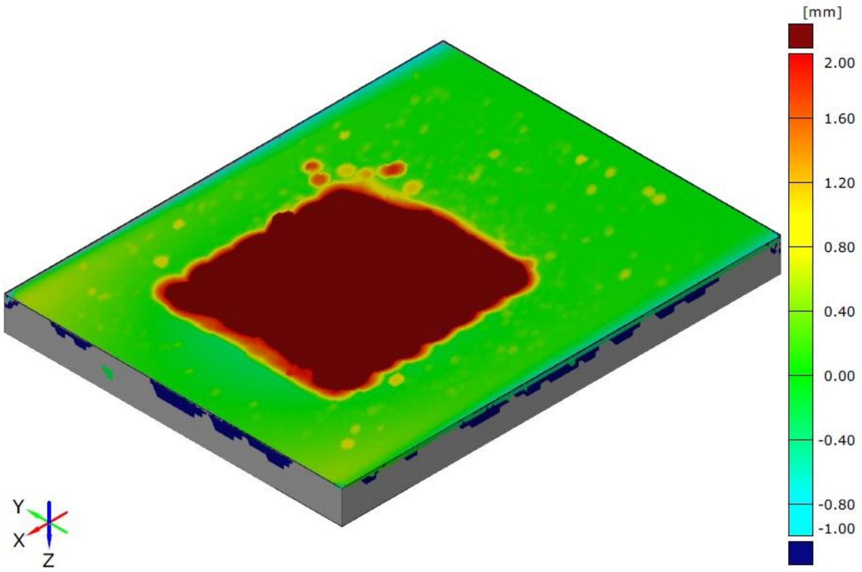

Fig. 12 Scanned surface deposited with welding parameters of wire feed rate 4m/min and 21V

4. Conclusion

From this experimental research, we can conclude that we get best results from substrate 5 with the welding parameters shown in Table 2. Substrates 1, 2 and 3 did not meet our initial condition that we have a thickness of 2 mm over the substrate. Moreover, spots between welding lines made substrate visible. Substrate 4 was very close to the satisfaction of the initial condition of 2 mm thickness above base material, but in two spots thickness was less than 2mm.

Table 2 Best welding parameters

Substrate No.	Gas flow $[l/min]$	Torch speed $[mm/min]$	Wire feed rate $[m/min]$	Voltage $[V]$	Welding wire
5	10	300	4	19	Durmat OA Ø1.2

Substrate 6 also satisfies our initial condition, but in this case, there was an increased deformation of the substrate. By scanning and analyzing welded substrate we have saved much time in the future that would be lost by grinding and polishing the substrates that do not meet the initial requirement of 2mm thickness above substrate. Further research is the grading and polishing of the substrate that meets our conditions, analyzing material, hardness and wear resistance.

5. Acknowledgment

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6. Literature

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