Recycling Microwave Oven Transformers To Build Up An Arc Welding Process

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Abstract : Recycling is one of the creative and developed engineering act in any modern society and people around the world have become aware of environmental problems. Such as, waste of materials, electric components, gases, liquids…etc. By growing of any society, the concern and knowledge of environmental problems growing too, because the waste keeps flowing and for sure overstocking. Therefore, engineers should come with creative ideas about recycling those wastes in order to save the environment and reduce their risk on the society. The aim of this paper is to recycle an important part of wasted or broken microwave oven called transformer by using it to build a simple and useful arc welding machine. The transformer is known as high voltage transformer and in this project, we will reassemble it by changing the secondary coil to come up with a transformer with low voltage and high current output. Setting up two transformers parallel to each other in an electric circuit will lead to even higher output current causing the workpiece to melt as an important stage of a fusion welding process. Thus, in this work the author will show the experimental procedures and theoretical point of view for recycling the high voltage transformer from two broken microwave ovens and turn them to a simple and useful arc welding machine.

1. INTRODUCTION

The father of science is a nick name has been given to a Greek scholar named Thales because he was the first person who made researches on electricity and magnetism. Michael Faraday who did the first experiment on induction by building a pair of coils in a toroidal closed magnetic core and as a result the (Faraday's induction law) has been named in 1831. Later, in 1882, Thomas Edison built the first electric plants in both London and New York to produce direct current (DC). As the doors opened for patents in this field, in 1886 George Westinghouse made the first alternating current (AC) supply system in Buffalo New York and followed by a patent in creation of a transformer in 1887. Nowadays, transformers are used in all around the world and it is the heart of any electric power supply system to deliver the power everywhere in a city and the benefit for this goes to all the people mentioned earlier [1]. On the other hand, in early nineteenth century Sir Humphrey Davy discovered that with high voltage electric circuit an arc (bright light) could be produced by bringing the two terminals close to each other. This bright light with an arc shape gave a considerable heat that can melt iron. Later, in 1860's Wilde an Englishman melted small pieces of iron together and that was the first patent recorded to welding. In 1881 Auguste De Meritens connected the carbon rod (electrode) to the negative pole of a current source and attached the workpiece to the positive pole to arc weld lead storage battery plates. Shortly after that, in 1887 a Russian guy known as Nikolas De Benardos made the first patent on arc welding by applying a fitted carbon rod with insulated handle connected to the positive pole of DC circuit so it could be controlled by hand easily. A bank of storage batteries was used as the power source for any arc weld process in early 1880's and the voltage could be controlled by number of cells arranged in series, while current by number of cells in parallel and by series resistors [2].

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Nowadays, most of the arc welding process machines depending on a transformer located in their power supply and a simple circuit of a welding machine power source showing the place of the transformer in next figure (1) [3].

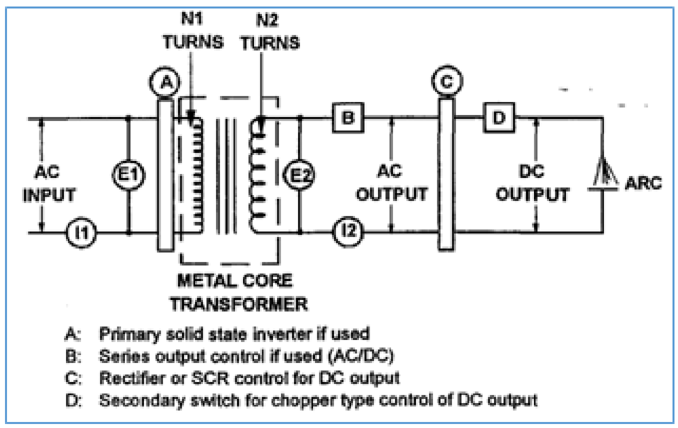

Figure (1): Showing a transformer in a power source of a welding machine [3].

Transformer is a device used to transfer electric energy from one electric circuit to another inductively through coupled conductors (coils) within a ferromagnetic core and its main purpose is to change the voltage level of an electric power source with a deferent voltage level depending on the surrounding magnetic field and flux. The transformer usually consists of two coils made of copper wires wrapped around a solid ferromagnetic core at two deferent levels. The two coils are not connected to each other and they are located within the same magnetic flux on the ferromagnetic core to transfer the power from one coil to the other. The primary coil or primary winding which is connected to the input power source transfers the power through the magnetic flux to the secondary winding or secondary coil to produce different voltage and current output depending on the ratio of the number of turns between both coils and Faraday's law [4 & 5]. For ideal transformer, the input electric power should equal the output electric power, which means the transformer will be influences both voltage and current only, while the power stays the same at the output [4, 6, and 7]. Next figure (2) showing a simple construction of a transformer and its important details. Therefore, any transformer depends mainly on a magnetic field produced through a ferromagnetic core.

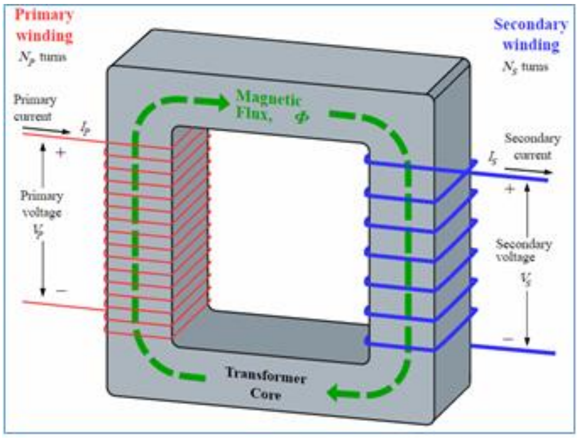

Figure (2): A simple construction of a transformer with its important [8].

The basics of producing a magnetic field in a ferromagnetic core depend on Ampere's law (eq. 1) which is simply explained by Chapman [4] and showing its main symbols in next figure (3). The important terms about a magnetic field need to be presented in order to measure what is called magnetomotive force and they are:

- Magnetic field intensity (H) = $\frac{Ni}{l_c}$ (Equation 1)
- Magnetic permeability of the material (μ)
- Resulting magnetic flux density produced (B) = μH = $\frac{\mu Ni}{l_c}$ (Equation 2
- Total magnetic flux in the core (Φ) = BA = μHA = $\frac{\mu NiA}{l_c}$ (Equation 3)
- Number of turns for the coil (N)
- The source current (i) = $\frac{V}{R}$ Where (V) is the voltage and (R) is the resistance (Equation 4)
- The cross-section area of the ferromagnetic core (A)
- Mean path length (l_c)
- Magnetomotive force (mmf) = Ni (Equation 5)

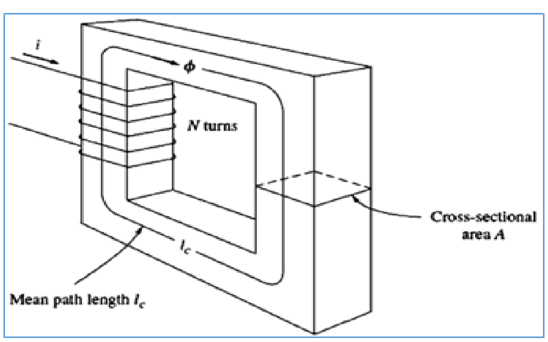

Figure (3): showing a simple magnetic square core with its important terms [4].

It is important to know that the magnetomotive force in any ferromagnetic core resulted from the primary coil should be equal for the ideal transformer to all around the core and can be transfer to the secondary coil with respect to the number of turns and that leads to the next equation (6).

$$mmf = (Ni_p)_{\text{primary}} = (Ni_s)_{\text{secondary}} \qquad \text{(Equation 6)}$$

Equation (6) shows a relation between the primary and the secondary coils, which means from that relation and by knowing the input power source and the primary coil number of turns, we can find out the resulting voltage and current coming out from the secondary coil by applying the voltage transformation ratio rule as it shows in the following equation (7) [9 & 10].

$$\frac{V_p}{V_s} = \frac{i_s}{i_p} = \frac{N_p}{N_s} \qquad \text{(Equation 7)}$$

2. EXPERIMENTAL PROCEDURES:

The main idea of this work is to recycle and setup two microwave oven transformers and connecting them to each other (in parallel and in series) to step down the voltage and produce higher current from an AC power source which can produce the proper heat when we shorten the two poles to melt and weld a low carbon steel (workpiece). Therefore, each of the two transformers were modified to work as step down voltage and increase the output current when using an AC power source. Thus, the secondary coil winding of each transformer was removed and changed with a thicker one and re-winded to have (0.033) of the number of turns of the primary one (Np), which means the results of the modified transformer has a primary coil with number of turns 30 times of the secondary one (Ns) and prissily (Ns = 10 turns). By connecting the two transformers the input voltage and current were controlled and measured using multimeter, while the output voltage and current were recorded by a multimeter depending on the number of turns ratio in the recycled transformers which is (0.033). In the beginning, each transformer was tested with four different inputs after modified and next table (1) showing the input and output voltage and current measured by a multimeter for the open circuit and figure (4) showing the actual connection for that, while table (2) showing the results of single transformer tested with short circuit and figure (5) showing the actual connection for short circuit. Later on, the transformers were connected to each other in two different ways, series circuit as can be seen in figures (6 & 9) and parallel circuit figure (7 & 8). Therefore, due to the purpose of this work we needed to measure only the short circuit in both connecting ways during the welding process (short the poles) for two different input voltage values (60 and 120). Table (3) is showing the input and output measurements for the parallel circuit when welding was applied, while table (4) showing the measurements of series circuit. Only short weld lines were made to reduce the buildup heat on the transformers and to keep them working properly, because there was no cooling system used during the process. Safety procedures were very important to work on this project, experts in both welding and electric connections were attended to follow the right safety procedures and prevent any possible disaster. First, we connected each of the two transformers separately to a power source to measure the output voltage and current in both cases open circuit and short one by changing the input voltages from the power source. Therefore, next table (1) showing the four different input and output values for a single transformer.

Primary Voltage (V)	Primary Current (I)	Secondary Voltage (V)	Secondary Current (I)
60	0.3	2	0
120	0.7	4	0
180	1.2	7	0
240	4.8	10	0

Table (1): *Measured input and output values for single transformer (in open circuit)*

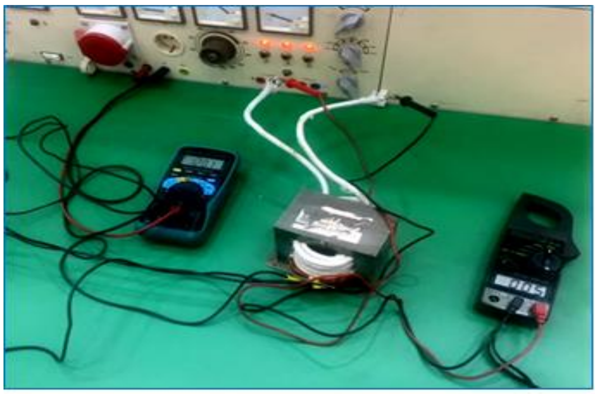

Figure (4): A single transformer connected to the power supply with open circuit output

Primary Voltage (V)	Primary Current (I)	Secondary Voltage (V)	Secondary Current (I)
60	2	8	211
120	4	15	384

Table (2): *Measured input and output values for single transformer (in short circuit)*

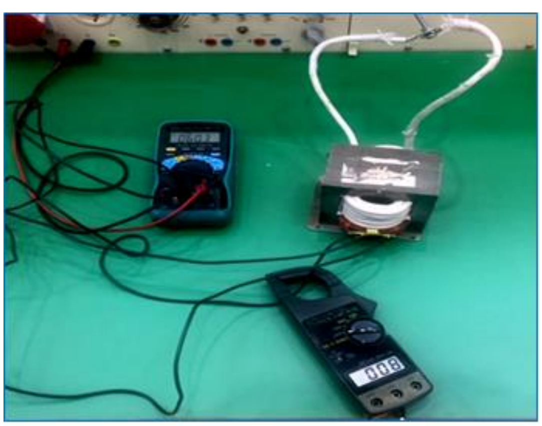

Figure (5): A single transformer connected to the power supply with short circuit output

Second, we connected the two transformers in two different ways; in parallel as can be seen in figures (7 & 8) and in series figures (6 & 9). In both cases, the measurements have been recorded of the input and output current to compare the two ways with each other as can be seen in tables (3 & 4).

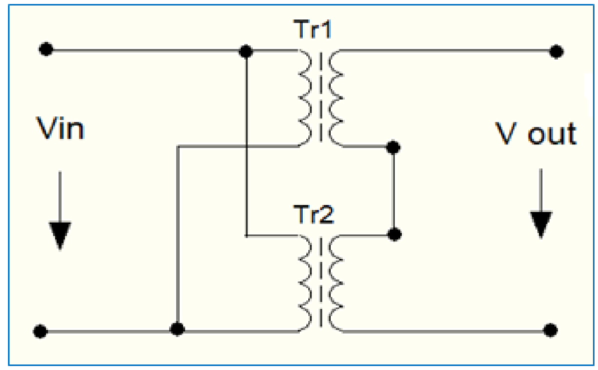

Figure (6): Schematic of transformers connected in series [11]

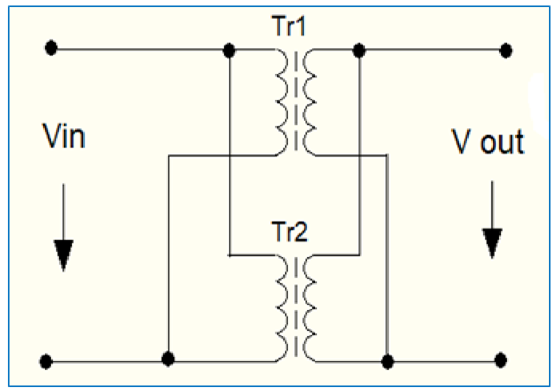

Figure (7): Schematic of two transformers connected in parallel [11]

Primary Voltage (v)	Primary Current (I)	Secondary Current (I)
60	14	287
120	23	479

Table (3): *Measured input and output values for two transformers (connected in parallel and short circuit)*

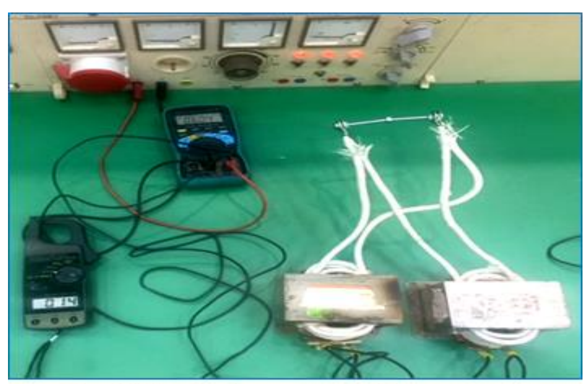

Figure (8): Two transformers connected to the power supply with parallel and short circuit

Primary Voltage (v)	*Primary Current (I)*	*Secondary Current (I)*
60	*18*	*221*
120	*36*	*420*

Table (4): *Measured input and output values for two transformers (connected in series and short circuit)*

Figure (9): Two transformers connected to the power supply with series and short circuit

Third, we used the two ways (parallel and series circuits) to weld a low carbon steel workpiece as a shielded metal arc welding process to find out if the setup and procedure are applicable or not. Thus, connecting one pole of the output circuit to the workpiece while the other pole is connected to the electrode as can be seen in figure (10) and when the poles are in touch with the workpiece the circuit is short, and the weld process should start.

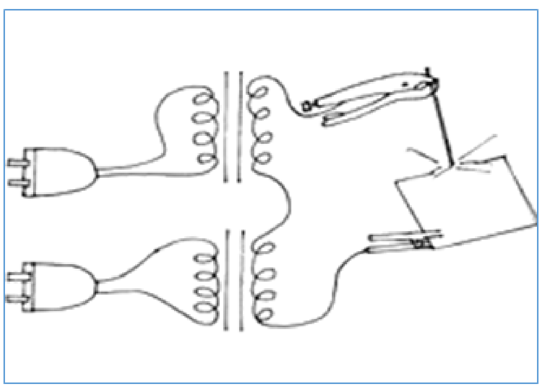

Figure (10): Schematic showing the connection of weld process by connecting two transformers in series [12].

Finally, discussion and analysis were made due to the gathered information and recorded results to buildup reasonable conclusions for this work.

3. RESULTS & DISCUSSION:

In this work the investigation of using two transformers from damaged microwave ovens to reassemble them and building up a shielded metal arc welder by increasing the output current and reducing the output voltage was positively applicable.

- **Results of single transformer**
  When we used one transformer and connected it to a power supply and open circuit to try how it will act after re-winding the secondary coil by 10 turns, table (1) showed that by applying equation (7) on the voltages and number of turns for both primary and secondary coils, we found that Np equal almost 300 turns if we are not neglecting the leakage or the efficiency of the transformer. That means the ratio of the two coils for the modified transformer is (0.033) so the step-down voltage transformer is (1/30) and that was confirmed with the results of table (1). By shorten the circuit, the current where be able to be measured and table (2) showed that the resultant current from this modified transformer is almost 100 times of the input current, which means equation (7) here is not applicable when we shorten the poles of the circuit because there was leakage in the magnetic flux and there was some lose in the transformer efficiency (not ideal). On the other hand, producing this amount of current gives us a good impression, which is that this transformer can be used as a welder device due to the high current produced.

- **Results of connecting two transformers in parallel**
  Connecting the two transformers in parallel increase the load of the suction amperage from the power source as can be seen in table (3) (for 60V it was 14A) and (for 120V it was 23A) in comparison with single transformer test which is (for 60V it was 2A) and (for 120V it was 4A) as table (2) showed. While the resultant current in the two trails of the parallel connection were as table (3) showed (for 60V it was 287A) and (for 120V it was 479A), but the single transformer was (for 60V it was 211A) and (for 120V it was 384A) as can be seen in table (2). Therefore, using two transformers and connecting them in parallel circuit can increase the suction current from the power source by almost 7 times in comparison with the use of single transformer, which means the load on the transformers will be higher and this is not desirable as can be seen in figure (11). On the other hand, connecting the two transformers in parallel produced around (20-27%) higher output current when comparing them with a single transformer performance and this is desirable for arc welding process as can be seen in figure (12).

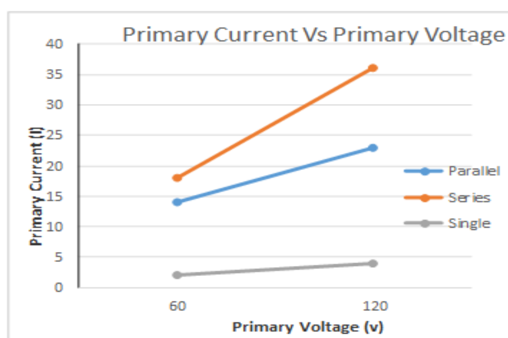

Figure (11): *Showing a chart of the measured primary current (consumption power) of a single transformer, two transformers connected in series, and two transformers connected in parallel when they are in short circuit (during welding).*

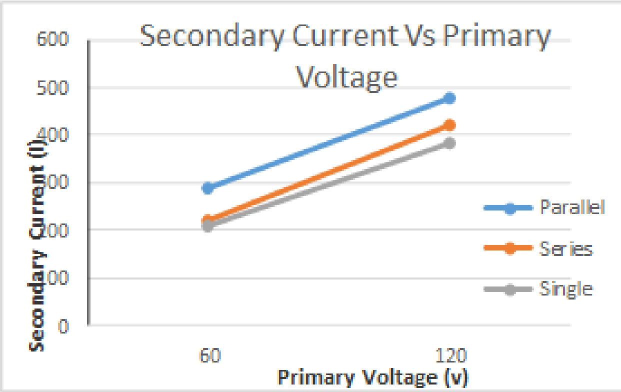

Figure (12): *Showing a chart of the measured secondary current (produced current) of a single transformer, two transformers connected in series, and two transformers connected in parallel when they are in short circuit (during welding).*

In both charts in figure (11 & 12), using two transformers and connecting them by parallel is preferable than connecting them by series due to lower suction current and higher production current when we apply a welding process, because lower suction current means lower power needed from the power source, thus longer time can be used to weld without heating up the transformers and better performance. Moreover, the production current will be higher to contribute melting the workpiece faster and easier. When we started to weld the welding was good then after seconds starts to lose the arc and the heat in the weld area, and we think that happens because of the worming up of the transformers and the performance efficiency went down and resulting in loosing output current. This means we were able to weld only short weld line around only (15mm) before we stop to cool down the transformers as one can see in next figure (13) for the weld made by this work on a low carbon steel workpiece with a thickness of (2mm). But when we apply the process on a workpiece with larger thickness of (5mm) we couldn't start the weld and the ignition of the arc was very poor and quickly shuts off and made like spot welds on the surface of the material as one can see in next figure (14).

Figure (13): Short weld lines produced by using two transformers connected in parallel on low carbon steel with (2mm) thick

Figure (14): Barely spot weld produced when applying the weld on thicker low carbon steel with (5mm)

Also, when we connect the poles without electrode just a workpiece connected to both poles, the workpiece gets hot very quickly depending on the size of the workpiece till it gets red in color from the high heat and that happens in seconds. This is a good approach and it can be used to heat the workpiece for many purposes such as heat treatment process, metal forming, and even spot weld with the appearance of the pressure. Therefore, we can use the transformers to build up not only a shielded metal arc welder but also, we can use it for metal forming and heat treatment processes as limited purposes.

- **Results of connecting two transformers in series**
  Connecting tow transformers in series resulted in increasing load suction from the power source as to be compared by the single transformer table (4) shows that the two transformers input readings current are (for 60V it was 18A) and (for 120V it was 36A) in comparison with single transformer test which is (for 60V it was 2A) and (for 120V it was 4A) as table (2) showed. While the resultant current in the two trails of the series connection were as table (4) showed (for 60V it was 221A) and (for 120V it was 420A), but we can see the single transformer was (for 60V it was 211A) and (for 120V it was 384A) as can be seen in table (2). Thus, connecting two transformers in series can increase the suction current from the power source by 9 times in comparison with the use of one transformer and higher than parallel connection in 23% as can be seen in figure (11), which means the load on the transformers will be higher and this connection is not desirable. On the other hand, connecting the two transformers in series produced around (5-9%) higher output current when comparing with a single transformer performance and for sure it is lower than the performance of the parallel circuit as can be seen in figure (12) and this conclude that a series circuit is not preferable when we apply it for arc welding process.

4. CONCLUSION:
In this work two transformers were recycled and modified from damaged microwave ovens and the secondary coil re-winded to 10 turns for the purpose of building up a shielded metal arc welder by increasing the output current and reducing the output voltage. The work was mostly successful and showed some conclusions as they follow:

- Using two microwave oven transformers to produce high current from 13 to 21 times the input current used from the power source, 13 times recorded when the transformers are connected in series, while 21 times the input current recorded by the parallel connection.
- Connecting the transformers in parallel is more reasonable for building up an arc welder due to higher current production and lower load suction from the power source as proved in this work when compared with the ones connected in series.
- Welding was possible for only thin material and for short weld line only about (15mm) after that the arc shuts off and the weld process stopped due to warming up the transformers and that effecting the performance of both transformers negatively.
- The transformers can be used not only for arc welding process, but it can be used for some other processes, such as; heat treatment, metal hot forming, and spot welding process. This can be done by heating up the material using the transformers when the circuit is shortened with the workpiece.
- This work can be improved more in the future by adding more than two transformers and connecting them under cooling system to have better performance and to produce longer weld lines.
- Recommendation please be aware when you use these kinds of transformers, because they produce very high voltage and electric shock may result with unsafe or inexpert usage.

5. REFERENCES

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