Design and Analysis of Ultrasonic Polypropene Corrugated Box Welding Machine

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ABSTRACT

A wide style of ultrasonic corrugated plastic box welding machine options are available to you. Ultrasonic Polypropene corrugated box welders as a special purpose machine for variable sizes of Polypropene boxes that is a no bench type-welding machine to weld pp boxes is made with innovative technology at its perfection. "SANITEK PLASTOWELD SOLUTION" are a reliable manufacturer, trader, importer and exporter of the industry and established within the year 2010. They are the favoured name within the market place for providing very best quality assortment of plastic welding machine box, ultrasonic handgun, ultrasonic tube sealing machines and plenty of more products are designed and made by them. Ultrasonic welding provides good welding aesthetics. Manufacturing of ultrasonic Polypropene box welding machine is obtainable by "SANITEK PLASTOWELD SOLUTION". No scratch guarantee for packed items. Polypropene corrugated boxes are nowadays used more as compare to the normal corrugated boxes, which were stapled and now corrugated box are joint by using ultrasonic welding. There is less rejection of packing items. A large form of ultrasonic Polypropene corrugated box welding machine options are available to you. No corrosion of joints means healthy packaging. This machine can weld one or more welding spot together which make it production friendly. With vision to sale its products in larger base company has laid emphasis on research. These are specifically designed to confirm easy handling reliable welding results, reproducibility while advancing, and optimizing the machine.

Keywords: Polypropene (PP) corrugated box, Ultrasonic Welding, SANITEK PLASTOWELD SOLUTION.

1 Introduction

Ultrasonic welding, quite possibly the most broadly utilized welding strategies for joining or welding the thermoplastics. Ultrasonic welding technique utilizes the energy of higher frequency range of (20-kilo-hertz to 40 kilo-hertz) and converts it to low adequacy range of (1 µm to 25 µm) mechanical reverberations. The Reverberation's produced by ultrasonic system create heat at the point of contact of the work pieces which are going to weld, bringing about liquefying at the contact point of specimen material and weld formation once it cools down. This welding technique is one of the quickest known procedure, having time of weld regularly somewhere in the range of 0.1 and 1.0 seconds.

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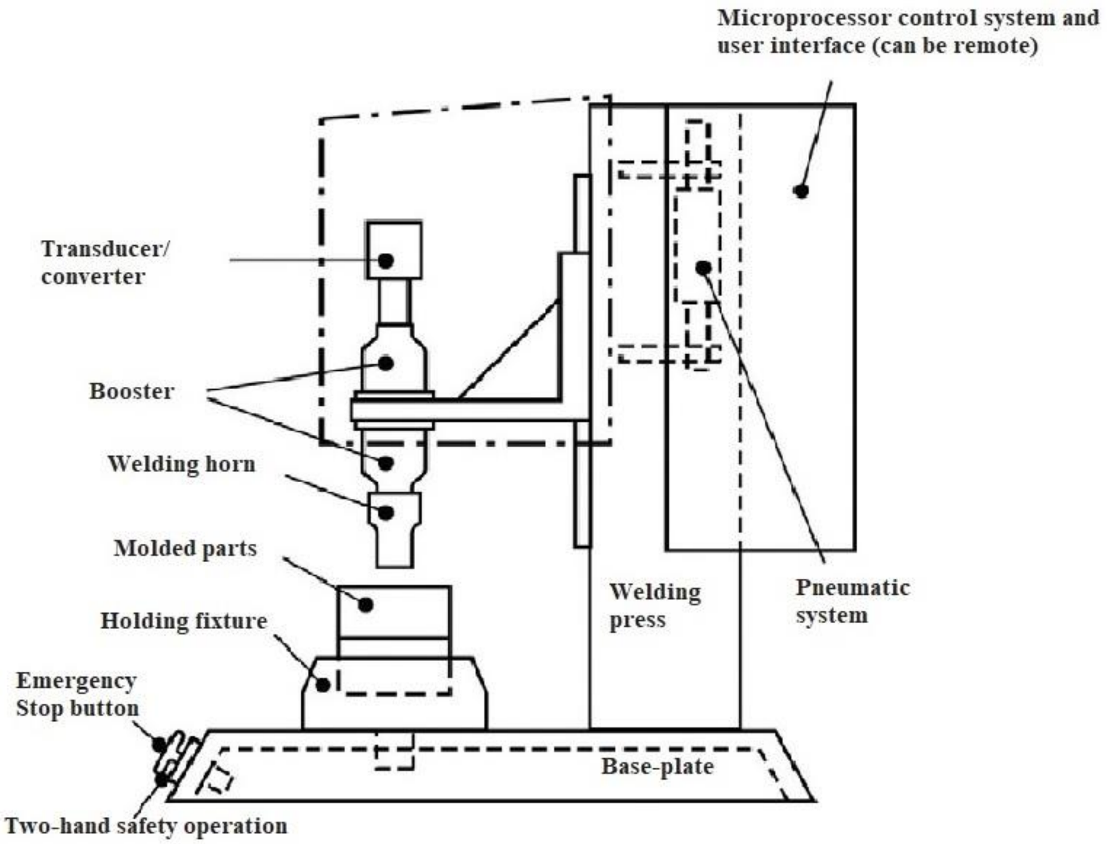

Figure 1: *Layout of ultrasonic plastic welding machine [5]*

2 Equipment

Various Parts for ultrasonic welding comprises an electric power supply, a converter and a booster connection for increment or diminishing the abundance of vibration, a Sonotrode (horn), apparatuses, or fixtures to help or for adjusting the welding parts, and an Assembly of Actuator i.e. The Booster, Converter, Sonotrode (horn), and other required pneumatic controls for the system.

2.1 Electrical Power Supply

Electrical power supply changes over a frequency range of 50 Hz to 60 Hz low voltage signal to a high voltage signal at the ideal recurrence (commonly ranges in 20 Kilo-Hertz). Electrical/Power supply might incorporate an implicit controlling feature for the welding process and for other functions. Electrical supplies are accessible by changing the degrees of interaction control, from fundamental units to the chip-controlled units. Electric supply yield goes from 100 to 6000 W.

2.2 Transducer

The transducer, otherwise called the converter, is a vital part of the ultrasonic system framework. It changes the electricity supplied by the power supply over to the mechanical reverberations, which are being utilized for the interaction of welding. Recurrence of vibration ranges between 15 – 70 kHz; in any case, the well-known frequencies utilized in this type of welding ranges between 20 kHz or 40 kHz. The adequacy or top-to-top sufficiency is the distance the converter travels during mechanical reverberations. The common value of conversion ranges from 20 μm for a 20 kHz converter and 9 μm for a 40 kHz converter.

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2.3 Horns

Sonotrode or a welding horn is a resonating device, which transmits the mechanical vibrations generated from transducer to the work piece; furthermore, it is particularly intended to suit the essentials. Three normal horn types are Step, Exponential, and Catenoidal.

2.4 Actuator

The Welding press otherwise called Actuator, principally houses the transducer- booster assembly and Sonotrode (horn) gathering (otherwise called the stack). It is essentially utilized for bringing down and raising the horn assembly and to put force on the work piece in a repeatable and controlled way.

2.5 Fixtures

Fixtures are generally needed for adjusting the parts and to hold them fixed while welding. Parts should be hold in the arrangement as for the finish of the Sonotrode (horn) in order to obtained uniform pressing factor in parts remains in the welding process, and the interaction should be in a repeatable manner. Fixtures should likewise grip the specimen parts fixed in order to communicate the ultrasonic energy effectively. There are mainly two types of fixtures namely Rigid and Resilient fixtures.

2.6 Control System

Nowadays, Ultrasonic machines are outfitted with a chip controlled Electrical supply which works in a period mode (Open loop mode) in order to apply energy for a required amount of time as well as in a peak power mode (closed loop mode) in which electrical supply observed all through the process of welding and transmitted vibrations are ended when a specific electrical supply level or power level obtained.

2.7 Working Principal

The arrangement of Ultrasonic Electrical supply for the most part comprises of Driver unit, Intensifiers, coordinating with Transducers, Driver unit and input unit segments. Principal of ultrasonic system is as displayed in the below diagram.

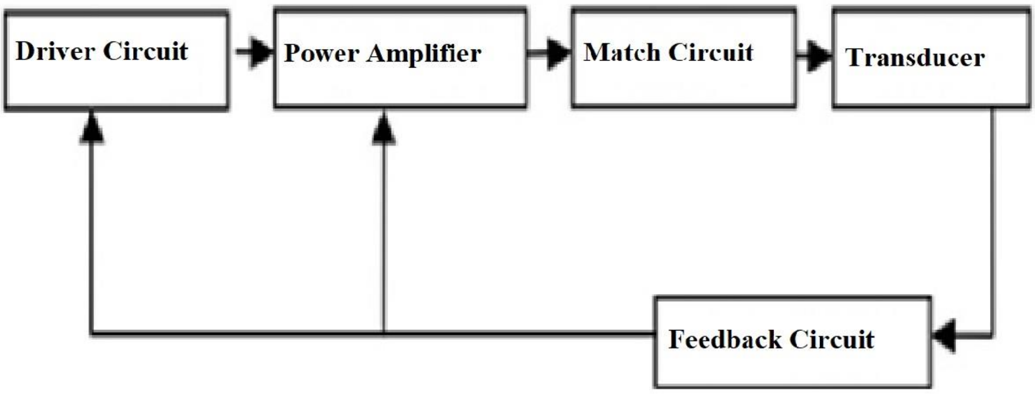

Figure 2: *Principle of Ultrasonic generator [1]*

The sequence of operations is as follows: –

Stage 1: The parts to be welded are set into a finding holder.

Stage 2: The ultrasonic instrument slips to apply a bracing pressing factor between the weld parts.

Stage 3: When ultrasonic force streams for a given time frame, the instrument then, at that point vibrates at a frequency 1 - 40 kHz.

Stage 4: The base metals are then precisely blended causing a metallurgical connection between parts. The parts are promptly welded. There is no hold time or restoring time.

Stage 5: Force is taken out and machine unloaded.

2.8 Machine Types

Various diverse welding machine designs are there, contingent upon the planned extent of activity. An incorporated machine comprises of all the parts equipped in a single unit and as a rule, there is only requirement of an association with compressed air and the electrical supply or power to become functional. These kinds of machines are generally utilized for manual loading and unloading of welding work piece. A segment framework comprises of interconvertible electrical or power supplies, Fixtures and Actuators and can be custom made as per the requirements.

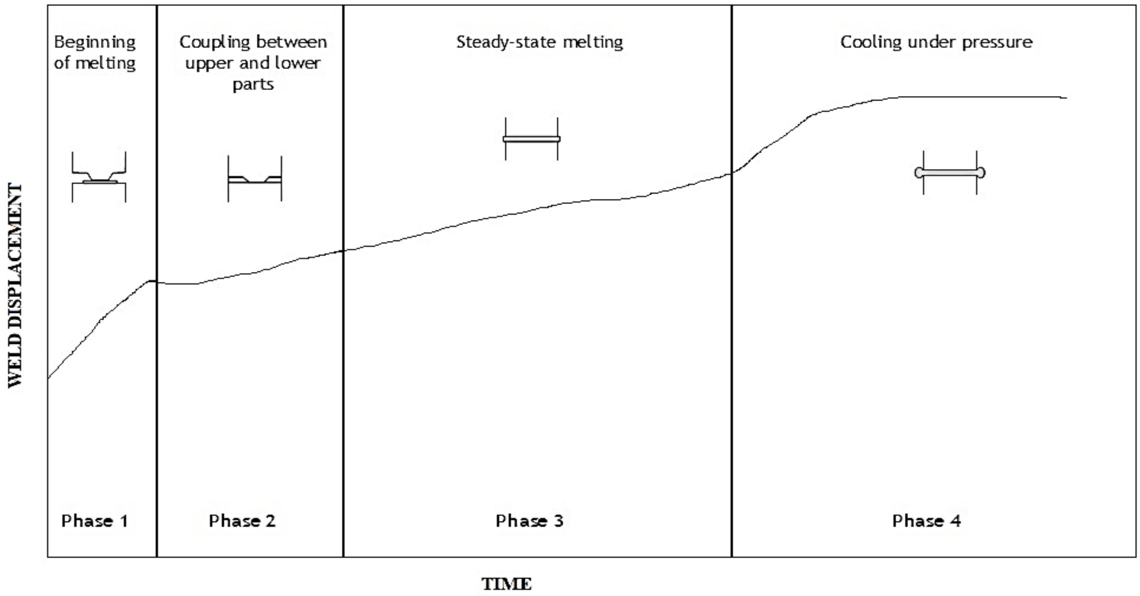

Figure 3: *Machine Types [5]*

3 Problem Statement

Presently client is utilizing welding machine outfitted with single horn welding framework. Which brings about weakness and higher creation time. For finishing one box, time required is all most 2 min. So there is a need to foster machine with 4 welding horns, so that in single stroke 4 welding focuses can be covered with 60 % efficient and higher usefulness. Likewise, for greater size boxes, 4 welding can be accomplished in one stroke. For successive activity rationale, we are utilizing PLC framework with HMI screen of SELEC Company.

3.1 Objectives

- Procurement of Ultrasonic tuning framework
- Mechanical assembly development.
- Pneumatic cylinder choice and improvement of sliding joint.
- Analysis of mechanical design.
- Testing of complete framework.

3.2 Scope of Project Work

- Development of machine with welding arm 1050 mm length with load limit of 50 kg thinking about Factor of safety of 2.
- Design the total framework utilizing CATIA V5R20.
- Analysis to be finished utilizing ANSYS Workbench for load limit of 500N.

- Utilization of material Mild Steel.
- Hypothetical estimation for material choice and Comparison with logical Information.

4 Literature Reviews

A concise history of the Ultrasonic welding system has been archived in the current review. It reviews theearly advancement of different sorts of ultrasonic welding systems. It additionally reviews design and developments, simulation of stress, strain, and deformation analysis of an ultrasonic welding system.

According to Chen Wei+ and Li Suxun [1]. "The research of ultrasonic equipment applied in non-woven welding" ICCSIT 2011. This paper primarily focuses on atomization of Ultrasonic welding system, which is made out of the high frequency ultrasonic electrical supply and the transducer. The high frequency ultrasonic electrical supply gives needed electrical supply to the transducer, and the transducer changes the electric energy into ultrasonic kinetic energy. This paper is centre around the hypothesis investigation and the plan of the electrical supply. In view of examination of ultrasonic welding technique, as per the need of applications of particular prerequisites we can design the power amplifier, Rectifier filter circuit, frequency track circuit, drive, matching circuit and protection circuit. Furthermore, analysed the essential piece of the rectifier channel circuit, power change and various parts, gave the limits of calculation and determination of method.

According to Somen K Bhudolia, Goram Gohel, Kah Fai leong and aminul Islam [2]. "Advances in ultrasonic welding of Thermoplastic composites: A review" MDPI 2020. Describes the various advances obtained in ultrasonic welding of thermoplastic composites. In this paper, the detailed progress made by the scientific and research community to date in the direction of the Ultrasonic welding of thermoplastic composites is studied. The ultimate aim of this paper is to review the recent developments obtained in welding technique for thermoplastic composites and for dissimilar materials.

According to K.H.W Seah, Y.S Wong and L.C Lee [3]. "Design of Tool holders for ultrasonic machining using FEM" Journal of material processing technology. The reason for this examination is to research the plan of Sonotrode (Horn) or proficient device holder for the ultrasonic welding machining measure by utilizing the FEM technique to break down the appropriate plan qualities for the Sonotrode, contrasting the outcomes and those estimated tentatively utilizing horns manufactured in-house just as those provided by a machine developer.

5 Materials and Methods

For Manufacturing of composite parts, like the parts of airplane, or the parts of vehicle, requires Molds of complex structure, results in considerable expansion of cost. Nonetheless, a particularly unpredictable part can be produce through the collecting of little parts by utilizing diverse jointing procedures. There are a few jointing strategies utilized for composite materials as displayed in fig.

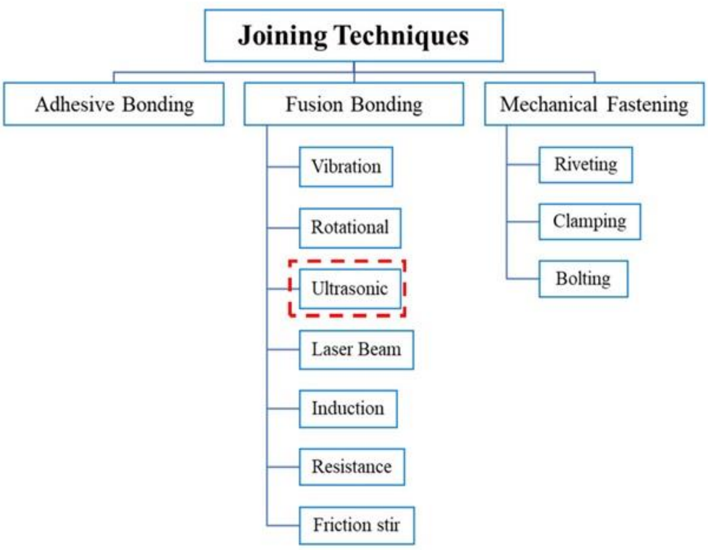

Figure 4: *Jointing techniques for composite materials [5]*

5.1 Ultrasonic Plastic Welding Machine Relevant Work

This type of welding is utilized practically at every significant enterprise where thermoplastics or specimen parts are needed in large quantity. A few applications as following: Automobile industries for making of vehicle parts, electronic industry etc.

5.2 Phase -1: - Sonotrode (Horn) Design

Sonotrode (Horn) is a resonating instrument, which transmits the reverberation to the work piece, and it is designed as per application requirements. The conventional strategies needed for design of a resonating horn depend on the balance of a minuscule component, which is under flexible activity, forces of inertia, and coordination over the length of Sonotrode (Horn) to achieve reverberation. The following differential equation accompanies the equilibrium condition:

$$\frac{d^2u}{dx^2} + \frac{d \ln A\,(x)}{dx}\frac{du}{dx} + \frac{\omega^2}{c^2}u = 0$$

Equation 1: *Equilibrium condition [5]*

Sonotrode (Horn) is a full-length acoustical bar with wavelength ranges to half. Slight change in the area or design of a Sonotrode gives it an addition factor, expanding the sufficiency of the mechanical reverberation it gets from the Actuators (Transducer-Booster assembly). There are three types of Sonotrode (Horn): -

- Step horn
- Exponential horn
- Catenoidal horn

1. Step horns comprises of segments with various however uniform area regions. The change in the areas is situated close to the intersection point. Because of the unexpected vary in cross sectional area near the intersection, these Sonotrode (Horns) have an extremely pressure focus around here and can fizzle whenever driven at over the top adequacy. Step horns have 9:1 gain factor.

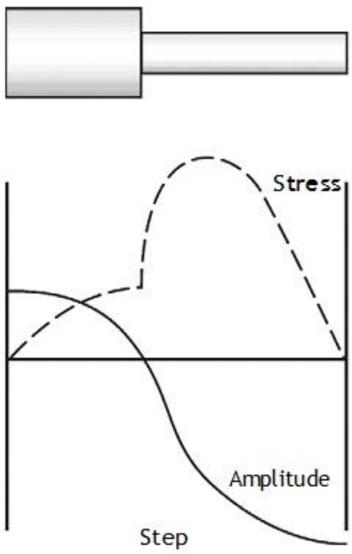

Figure 5: *Step Horn [5]*

2. In Exponential horns cross-sectional area changes significantly along length. This change in length conveys stress along a greater length. Exponential horns have less stress concentrations than Step horns.

These horns have low gain factor and considerably utilized where there is requirement of low amplitude and less power.

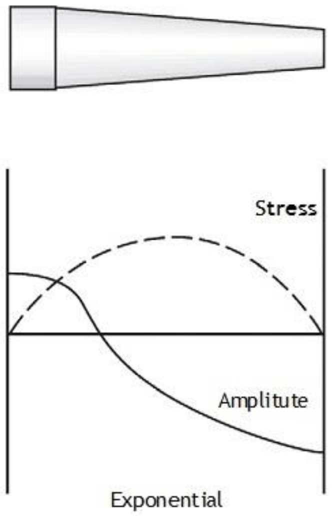

Figure 6: *Exponential Horn [5]*

Catenoidal horns also known as stepped horns have a slower change range in radius length through the intersection point. They are having low stress concentration and high gain factor.

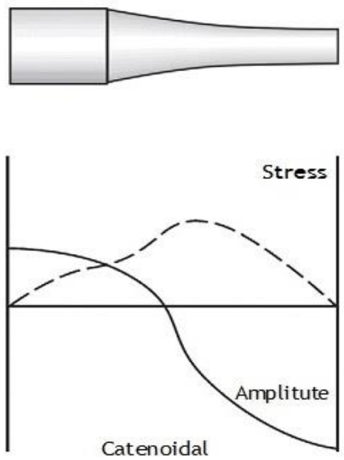

Figure 7: *Catenoidal Horn [5]*

5.3 Material for Horn

- Aluminum
- Titanium
- Steel

5.4 Phase-2: - Specimen Preparation

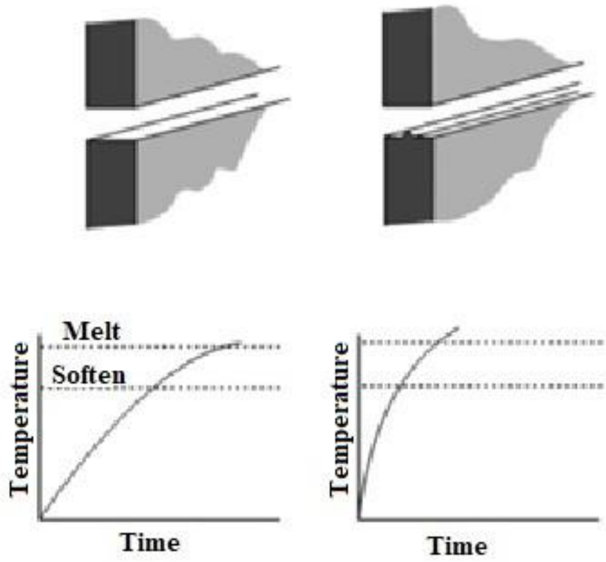

Figure 8: *Specimen preparation [5]*

5.5 Phase-3: -Experimentation

As indicated by various boundaries in the ultrasonic machine, as a matter of first importance considering the force impact on strength of welding. Then readings for various pressing factor esteems and test the strength at the interface. In the next stage, consider the impact of time on the strength of welding. Then slight change in the weld timing and notice the strength of welding at interface. Likewise, advancing the design of Sonotrode (Horn) by fluctuating distinct factors.

5.6 Phase-4: - Use of Finite Element Analysis Tools for Validation

Use of Finite element analysis tool for obtaining results is most important stage for any research work. It provides the verification of results obtained and information of system, which is carried out for Research process. FEA apparatuses like, CATIA V5R20, ANSYS etc. are used for Validation purpose in any research work.

5.7 Phase-5- Preparation of Final Report

The Final stage for any project is preparation of report.

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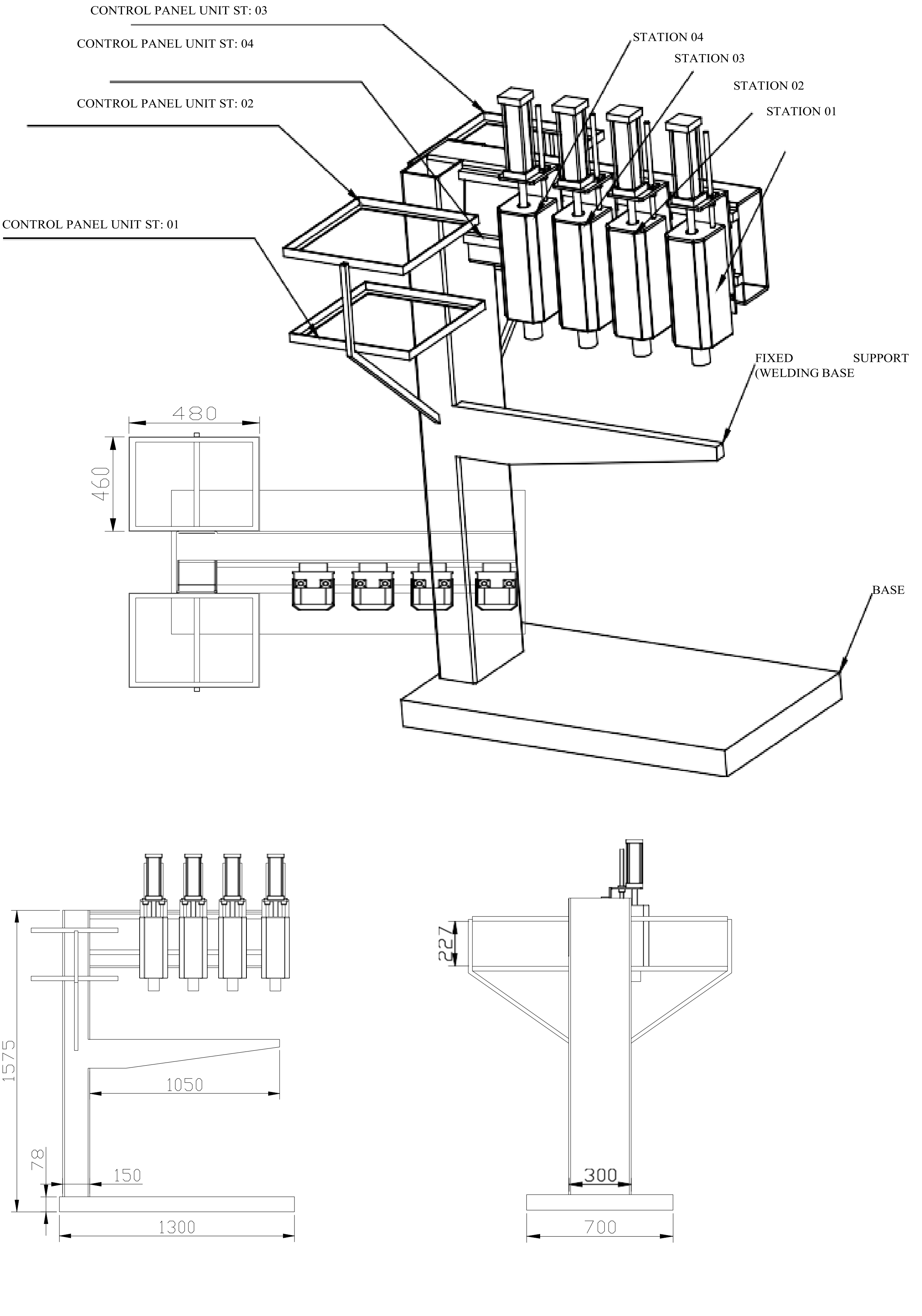
6 Theory and Calculation

6.1 System Design



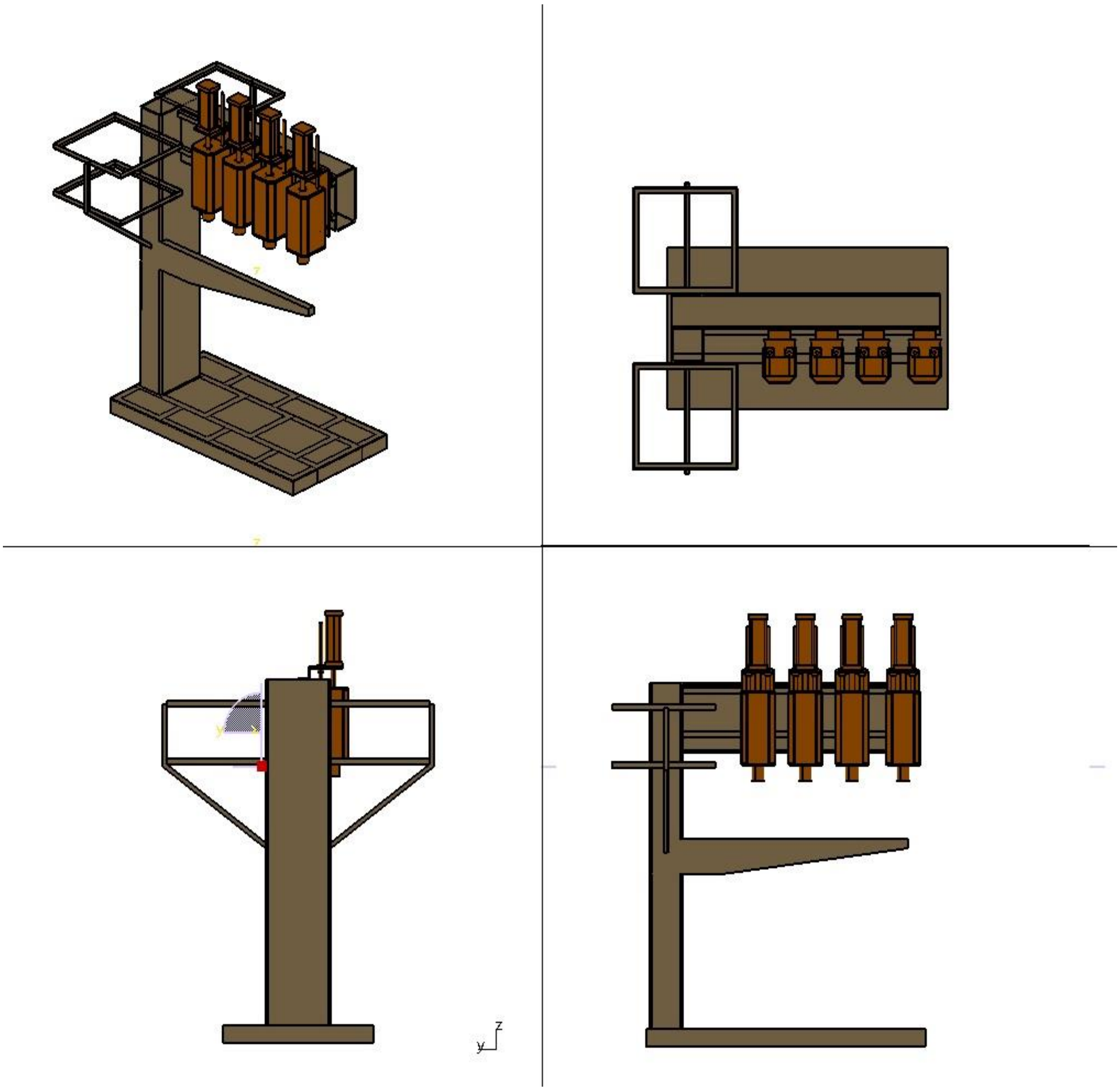


Figure 9: *System Design*

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6.2 Horizontal Beam Loading Condition

Pressure exerted by four pneumatic cylinder= 100 Kg
Self Weight of horizontal beam = 150 kg
Total load = 250 kg =2500 N
Beam material = Mild Steel

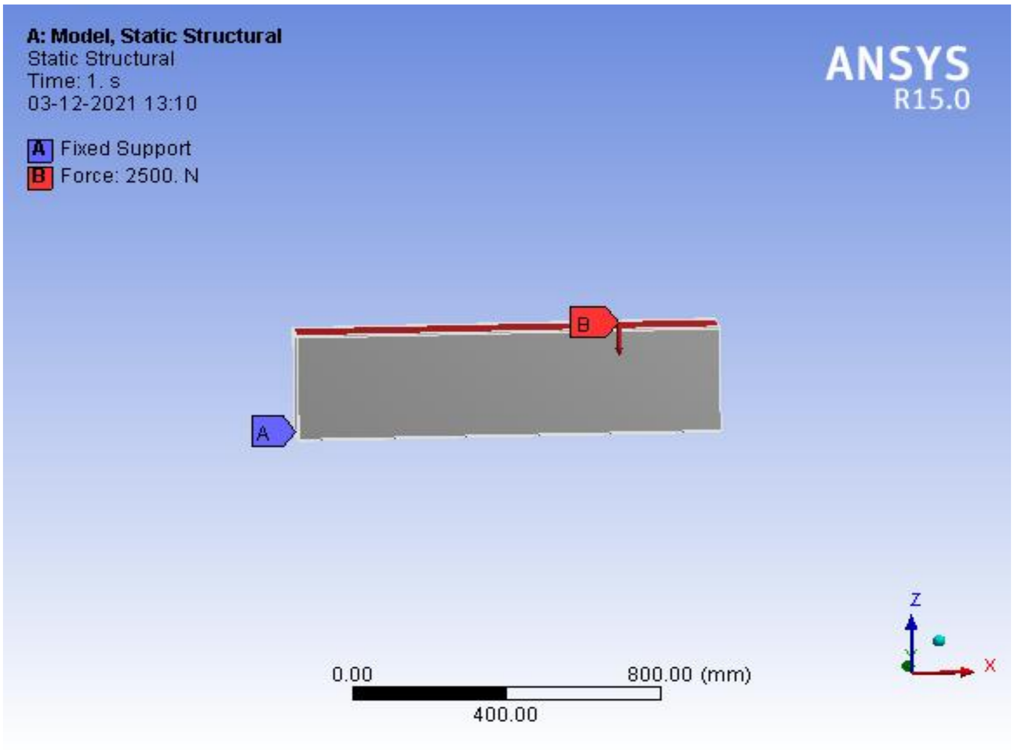


Figure 10: *Horizontal beam loading condition*

6.3 Equivalent Stress

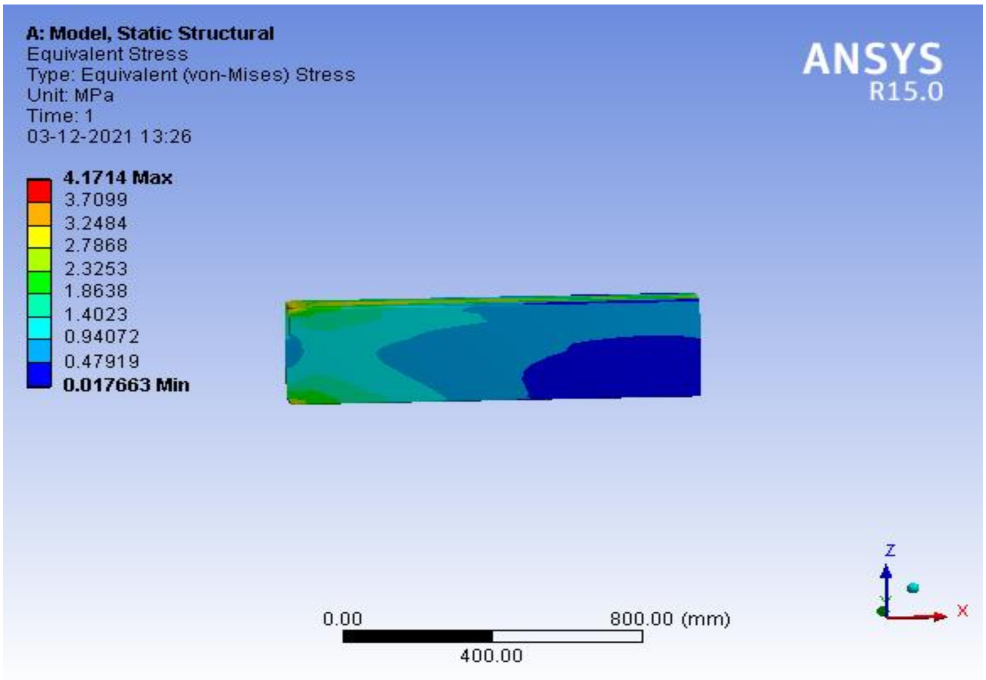


Figure 11: *Equivalent stress*

6.4 Total Deformation

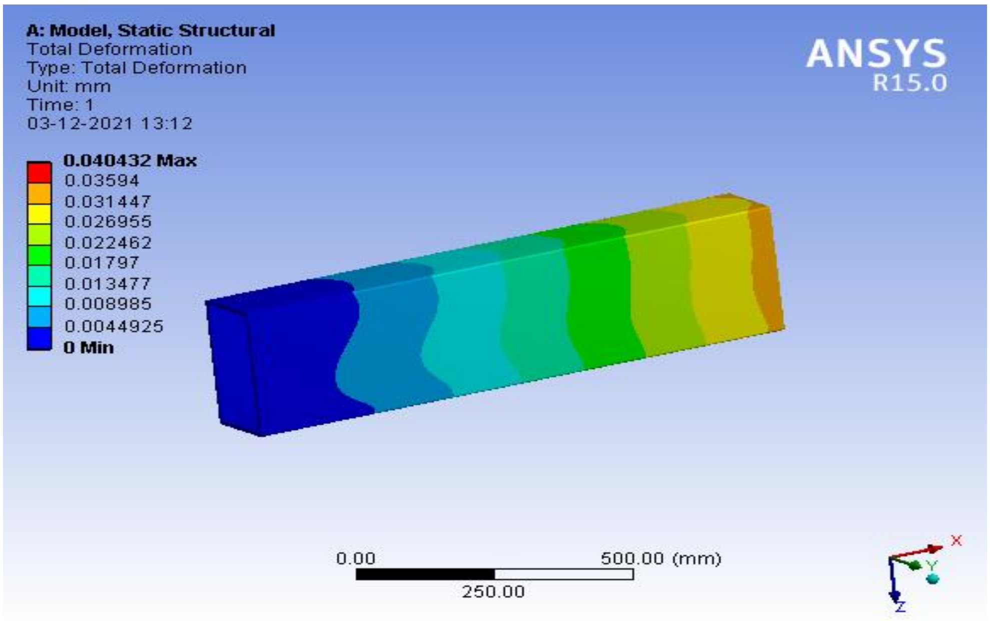


Figure 12: *Total Deformation*

From the above outcomes, we can say that acquired outcomes are under safe area since the stress obtained are under permissible limit of Mild steel (140 mpa). Here obtained stress value is 4.17 mpa. Therefore, design calculations are in limits.

6.5 Welding arm Analysis Results

Boundary Condition:
Self Weight of Arm: 50 kg
Load Applied on top surface of arm by four pneumatic cylinder: 100 kg
Total load = 150 kg = 1500 N

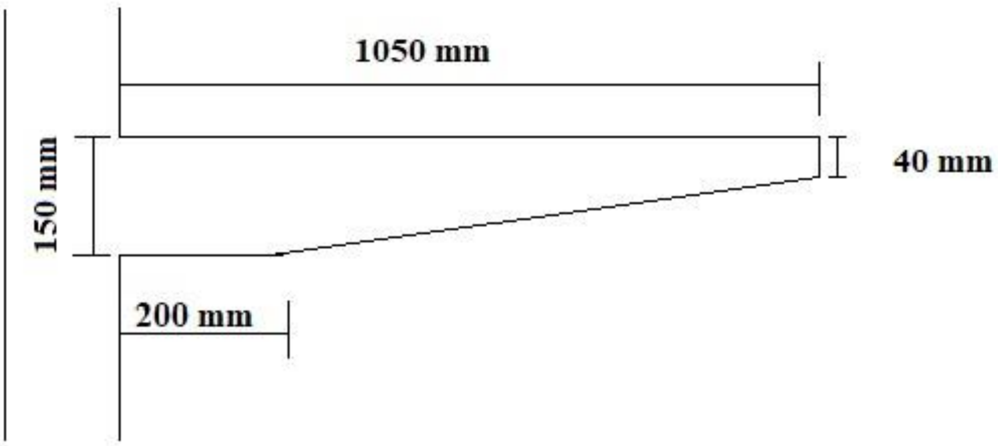


Figure 13: *Welding arm analysis*

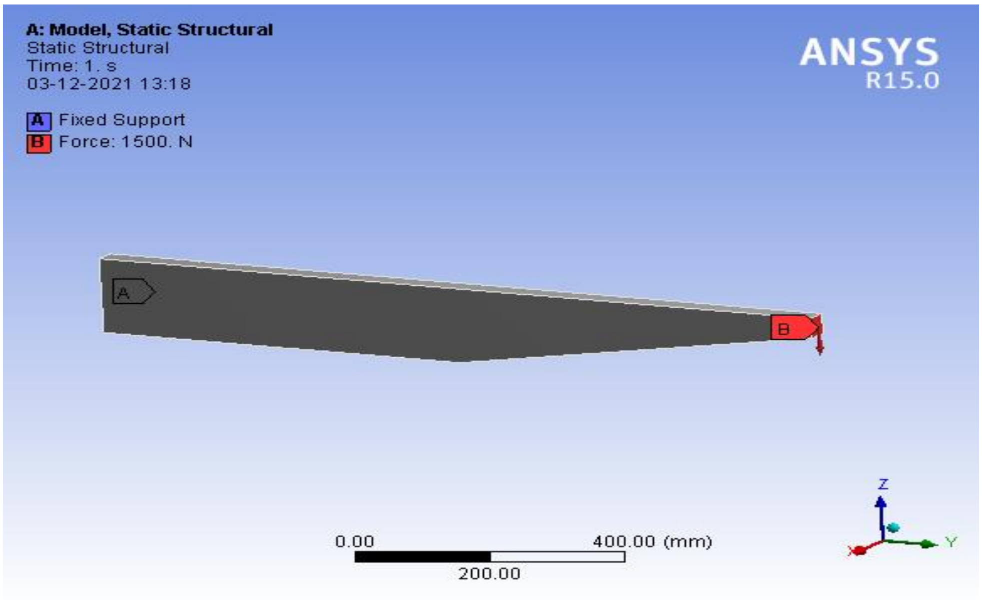


Figure 14: *Boundary conditions welding arm at load 1500N*

6.6 Equivalent Stress

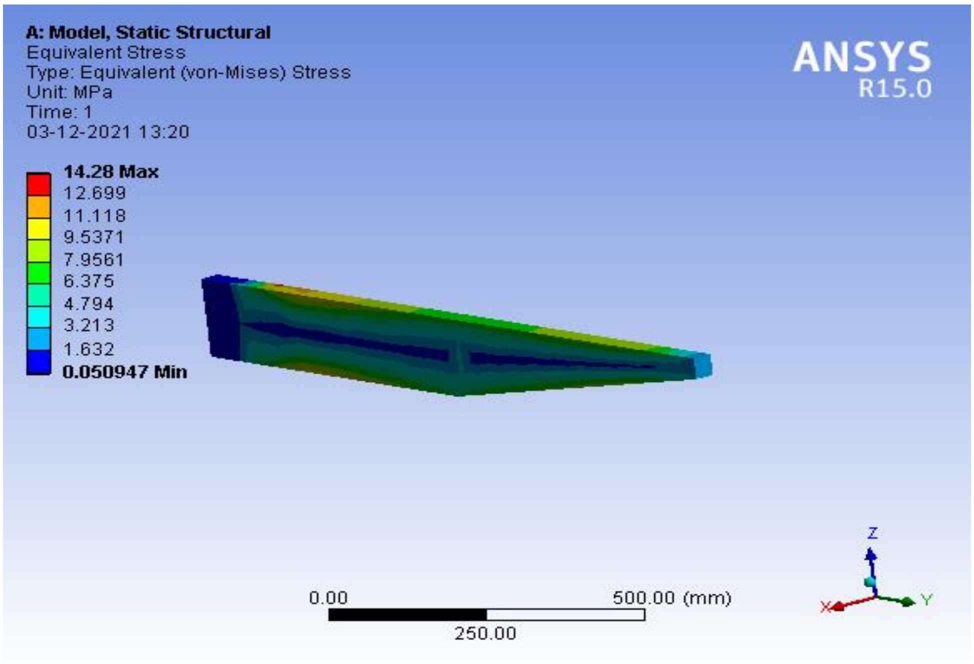


Figure 15: *Equivalent Stress welding arm at load 1500N*

6.7 Total Deformation

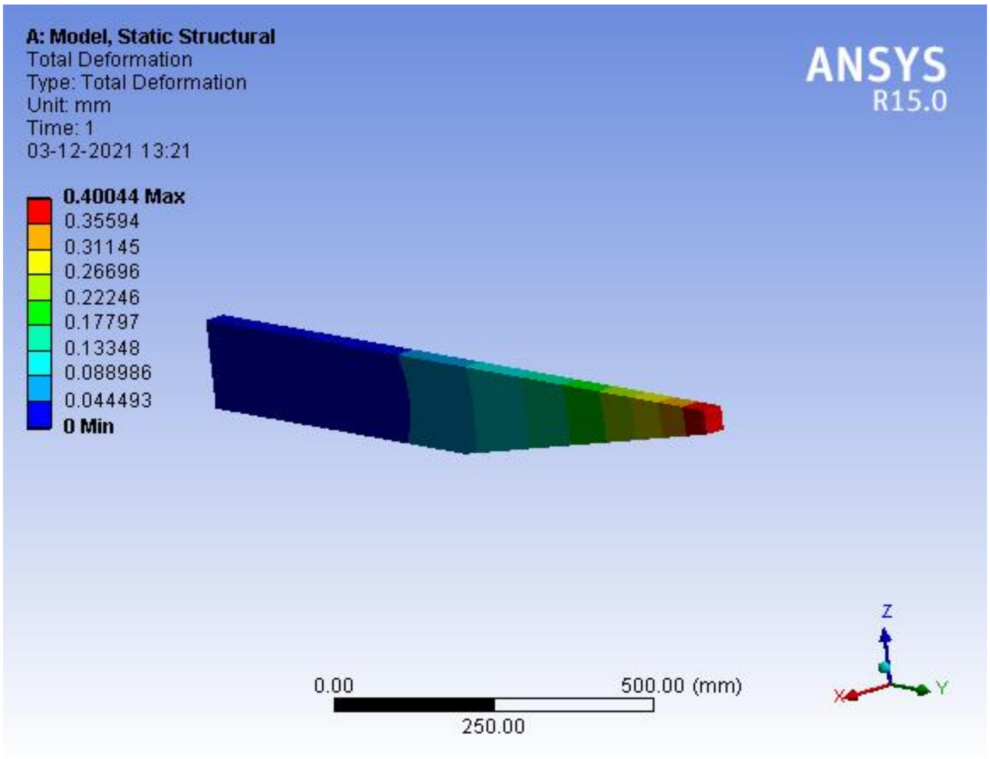


Figure 16: *Total deformation of welding arm at load 1500N*

From the above outcomes, we can say that acquired outcomes are under safe area since the stress obtained are under permissible limit of Mild steel (140 mpa). Here obtained stress value is 14.2 mpa. Therefore, design calculations are in limits.

7 Results and Discussion

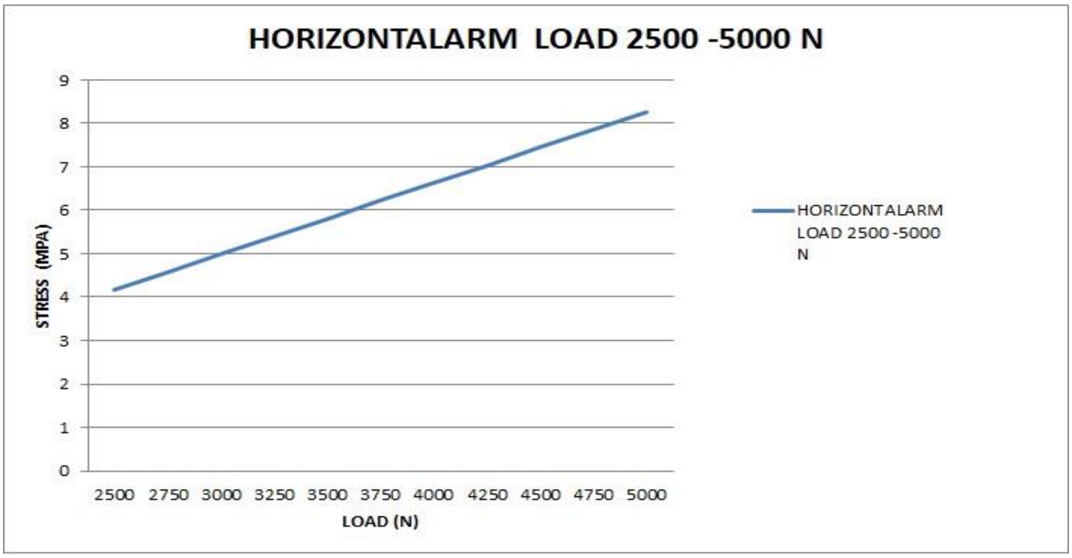
From the above outcomes, we can say that acquired outcomes are under safe area since the stress obtained are under permissible limit of Mild steel (140 mpa). Though our maximum prompted, stress in welding arm is 12.78 mega Pascal.

Table 1: *Horizontal arm load analysis*

HORIZONTAL ARM ANALYSIS LOAD 2500N -5000N		
LOAD (N)	STRESS (MPA)	DEFORMATION (mm)
2500	4.17	0.036
2750	4.58	0.04
3000	4.99	0.044
3250	5.4	0.048
3500	5.81	0.052
3750	6.22	0.056
4000	6.63	0.06
4250	7.04	0.064
4500	7.45	0.068
4750	7.86	0.072
5000	8.27	0.076

Table 2: *Welding arm load analysis*

WELDING ARM ANALYSIS LOAD 1500N -3000N		
LOAD (N)	STRESS (MPA)	DEFORMATION (mm)
1500	6.3899	0.1169
1650	7.0289	0.1286
1800	7.6679	0.1403
1950	8.3069	0.152
2100	8.9459	0.1637
2250	9.5849	0.1754
2400	10.2239	0.1871
2550	10.8629	0.1988
2700	11.5019	0.2105
2850	12.1409	0.2222
3000	12.7799	0.2339



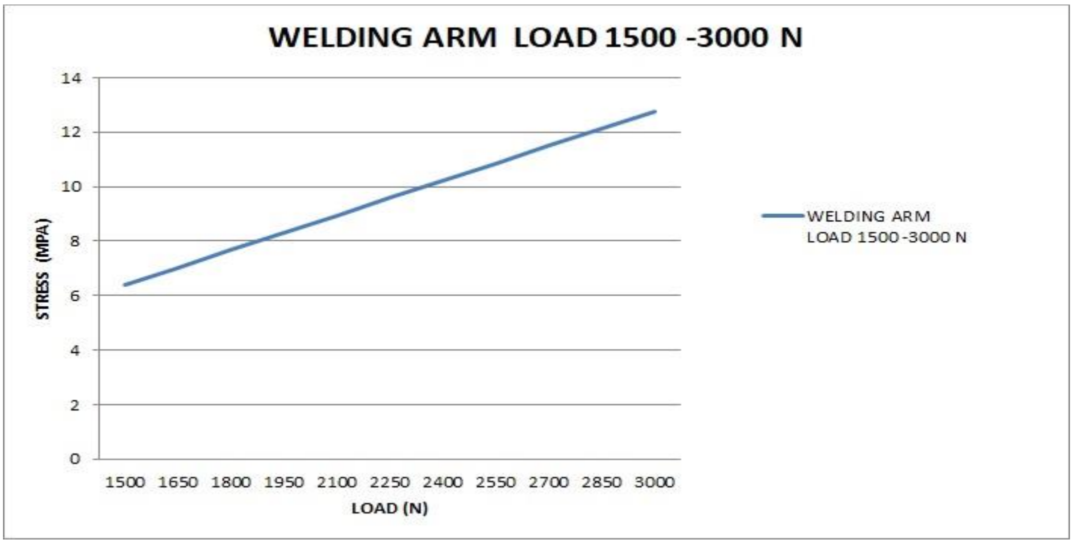


Fig 17: *Graphs of Horizontal arm and Welding arm*

In addition, when system analyzed for combined load analysis the max stress induced is 5.317 mpa, which is comparatively very less than the ultimate stress value of mild steel.

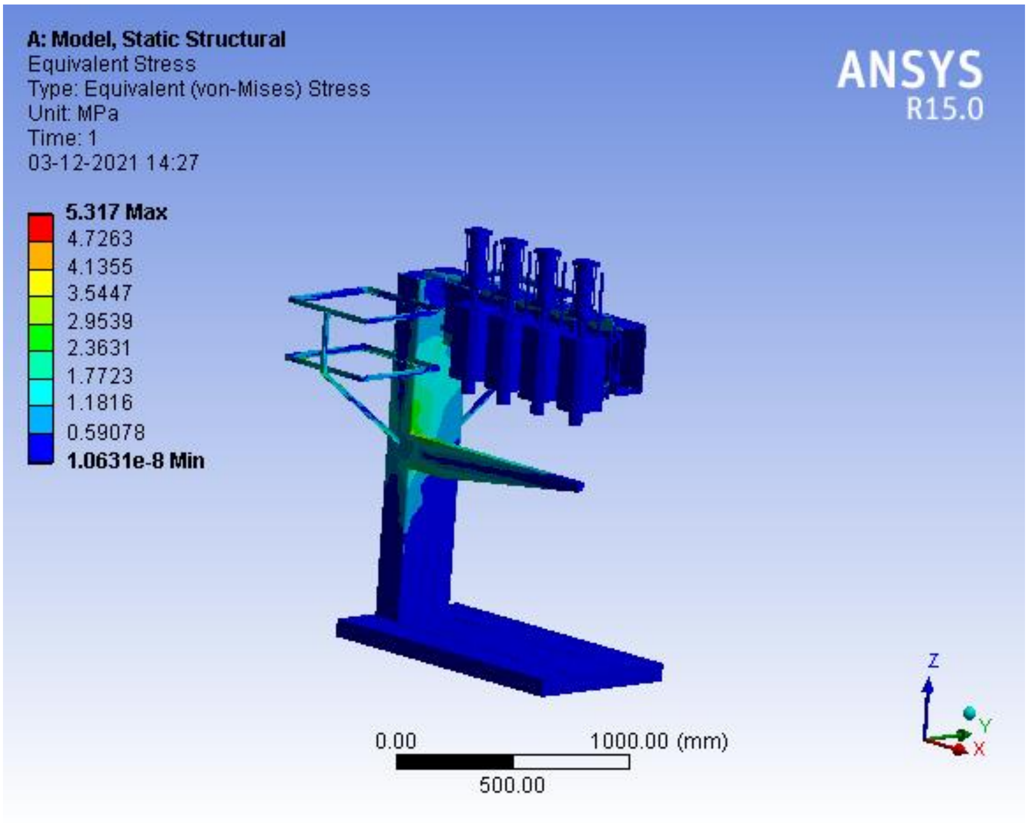


Figure 18: *Combined load analysis*

8 Conclusions

Thus, we conclude that our system design is safe under given loading conditions. In addition, the cycle time of ultrasonic system is up to greater than 50000 cycles, also maintenance required every 6 months for smooth operation of system.

9 Declarations

9.1 Acknowledgements

I take this opportunity to thanks Prof. A B Gaikwad (my project guide) and Sanitek Plastoweld solutions for guidance as well as for providing all the required facilities, which proves beneficial in completion of this project work.

9.2 Funding source

Sanitek Plastoweld Solutions

9.3 Warning for Hazard

Do not touch to end tip of horn when system is on.

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