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ENHANCING MECHANICAL CHARACTERISTICS BY ADDING NANOPARTICLES AND EMPLOYING LASERS IN HEAT TREATMENT

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With the development of laser technology in various fields of engineering and manufacturing in terms of many uses in these areas and in the field of improving the mechanical properties of different metals for their ability to withstand different thermal and mechanical stresses and stresses. Wherein this research paper the addition of nanomaterials and laser heat shedding on them and knowing their ability to improve. The design process of the simple model that complies with the requirements of the simulation process was in the solid works program. The investigated dimensions were (100×100×10) mm^3 in height, split up in the form of two portions. The partition itself is the path of the laser used. It is necessary to check the reliability of the mesh to form an appropriate mesh that can give accurate results. The nanoparticles where Al_2O_3 and TIC were used in different proportions with the base material. Which is steel, where these ratios were (0.3, 0.6, 1) wt %, where the results proved the process of adding nanomaterials has positive effects in terms of the materials' tolerance to heat, mechanical stress, and the surrounding conditions. Seen through the results with the increase in the concentration values of adding nanoparticles, get a significant effect on the results and the values of thermal and mechanical properties. The TIG (Tungsten inert gas) nanomaterial led to an increase in temperatures in the solid by 1 wt % compared to the rest of the concentrations and nanomaterials. The addition of nanomaterials in heat treatments has a positive effect on the amount of deformation, as the lowest value of deformation was obtained in nanomaterials at tic1 wt % compared to the rest of the concentrations. As for the stresses, the largest stress obtained is 10.502 GPa

Keywords: static structural, nanomaterials, heat treatment, tungsten inert gas, thermal stress

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1. Introduction

Nanoparticles can be made of tiny (50 nm) metallic groups. It is another sort of substance that gangs fascinating features: optical, attractive, synergist, and electronic, which could be personalized as a component of the particles' size and shape [1]. The intensity of aluminum hangs out after various warm medicines are confirmed by Trull tests. Various blends of pre-and post-welding warm medicines were proposed. The microstructure of the welded specimens was examined, checking electron microscopy and energy dispersive X-ray spectrum analysis [2]. $AlSi_{10}Mg$ parts handled by LPBF went through different warm medicines, for example, stress diminishing, toughening at high temperature, and T6 medicines. The warm development of the framework was then considered through differential filtering calorimetry and x-beam diffraction examinations [3]. Direct Metal Laser Sintering (DMLS) is beginning to be utilized for assembling practical parts. DMLS process starting points hinder surface pliable anxieties in Inconel 718 and CoCr compound parts. The surface remaining anxieties, microstructure, porosity, and hardness of the parts have been examined [4]. The importance of such studies lies in studying the variables of using lasers in welding, as this study is used to show the thermal stress and the effect of nanomaterials. It is necessary to find different methods such as these to increase the efficiency of laser welding.

2. Literature review and problem statement

The paper [5] Warm medicine could be utilized to enhance the laser sintering of polybutene-1 (PB-1). Crystallization occurs extremely quickly at temperatures below 90 °C, resulting in warpage during handling. Where the research paper reviewed the process of laser welding on graphite materials in an experimental manner, as it did not mention the details of adding nanomaterials. The paper [6] a minimal expense strategy for manufacturing microsensors exhibits on business soft drink lime glass is introduced. The half-and-half procedure is made up of a laser direct composing strategy and a laser-assisted post-warm treatment. This new manufacturing approach allows to get high-quality micro lenses exhibited with a breadth of 50 m. The principle of research work in the carbon dioxide laser on materials was the fabrication of micro lens arrays on soda-lime glass and did not depend on the addition of nanomaterials to improve the welding process [7]. At the same time, laser lipolysis can be used to eliminate fat while also repairing skin. Skin temperatures were recorded promptly post-treatment for every openness. Superficial treatment with surface temperatures exceeding 47 °C (50 °C and 55 °C at 5 mm profundity) normally causes epidermal and dermal injury. This study focused on the heat generated by laser in biological applications.

The paper [8] no ablative 1540 nm fragmentary lasers instigate an injury mending reaction, which can prompt rebuilding of the consumed scar surface. 17 grown-up affected roles with consumption marks of one year or more established and Fitzpatrick skin types I–III were remembered for assessment. No huge contrasts were found in skin pigmentation from laser treatment to non-treatment. The heat produced by lasers in biological applications was the main topic of this investigation and it was specialized in one type of laser. The paper [9] Photoluminescence (PL) attributes the nanometer-sized indistinct silica particles to the air and space. Distinctive PL qualities seen between the air-and vacuum-warmed examples are talked about. On the basis of the thickness utilitarian hypothesis estimations. This study worked on silicon lasers using an experimental method and nanoscale. The work was not done numerically and by changing the welding process.

The paper [10] potential models of the separate discharge fixate are introduced. However, Al_2O_3 is relied upon not to radiate intensity at room temperature. However, a compound photo-iridescence outflow range has been uncovered and its temperature dependence has been painstakingly examined. A few examples were submitted for reasonable warm medicine in an oxygen-rich atmosphere at (1000 °C). This study focused on the heat generated by laser in biological applications, and it was also specialized in one type of laser.

The paper [11] Silver nanoparticles have been orchestrated by particle implantation in soda-lime silicate glass. Changes instigated by the heater and pulsed laser pillar warm medicine are different. A mix of heater warming followed by laser pulses can induce regrowth. The main problem in previous researches is that the thermal aspect is not understandable and the amount of radiation emitted from the laser or the radiated diameter has not been studied. That is why the importance of the presented research paper lies in solving these problems. The process of simulating nanomaterials for surfaces when welding is somewhat new according to previous researches.

Because neither the amount of radiation emitted by the laser nor the radiating diameter have been explored, the fundamental issue with past research is that the thermal aspect is not comprehended in an intelligible manner. This highlights the significance of the research paper in addressing these issues. Nanomaterials mimicking surfaces during welding is a relatively new application.

3. The aim and objectives of the study

The study's objective is to minimize surface temperature and then reduce thermal stresses and deformation. By knowing the parameters required for the laser welding process, the sample deformations that occur because of high temperature can be reduced, and therefore these parameters can be used in complex welding applications.

To achieve this aim, the following objectives are accomplished:

– to identify the influence of laser parameters on thermal stress of steel;

– to identify the influence of nanomaterials on improving the mechanical characteristics.

4. Materials and methods

The design process of the simple model that complies with the requirements of the simulation process was in the solid works program. The investigated dimensions were (100×100×10) mm^3, split up in the form of two portions. The partition itself is the path of the laser used, Fig. 1. The reason behind the choice of these geometrical dimensions is to simplify the case and reduce the run time in the PC.

After the design process, it is necessary to check the reliability of the mesh to form an appropriate mesh that can give accurate results that can be used in the simulation and numerical study process, Fig. 2 and Table 1.

After completing the meshing process, the variable properties of the concentrations that were used for the materials must be added to the library of the ANSYS program that was used to make this simulation Table 2. The reason behind the choice of this parameters values is to take the exact values of these properties from a reliable source.

After adding the materials and concentrations used in the thermo-mechanical simulation, the heat treatment was done first by inserting a moving temperature representing the laser used in the path used in the geometry and its starting point Fig. 3, 4.

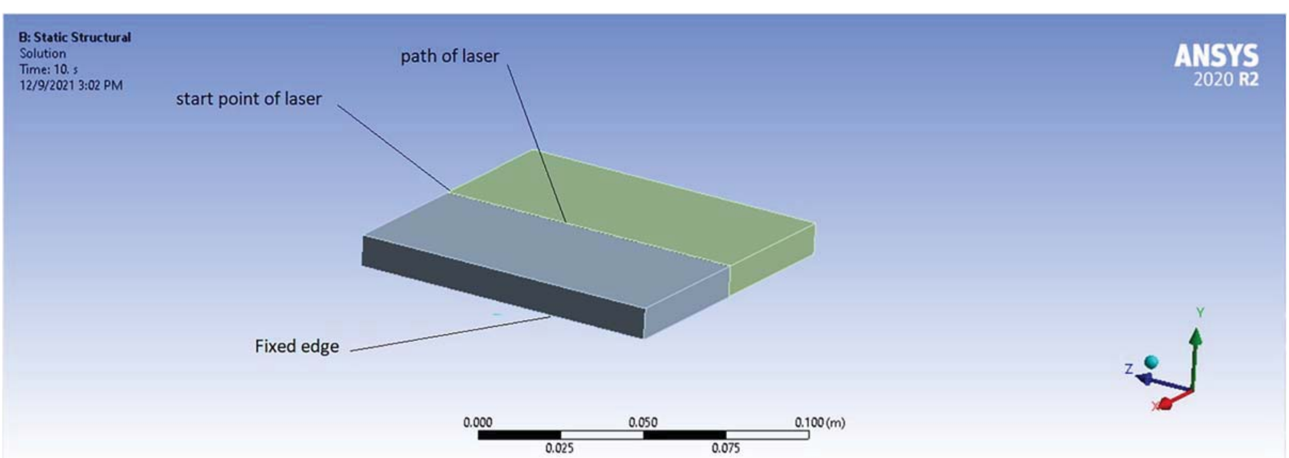


Fig. 1. Geometry

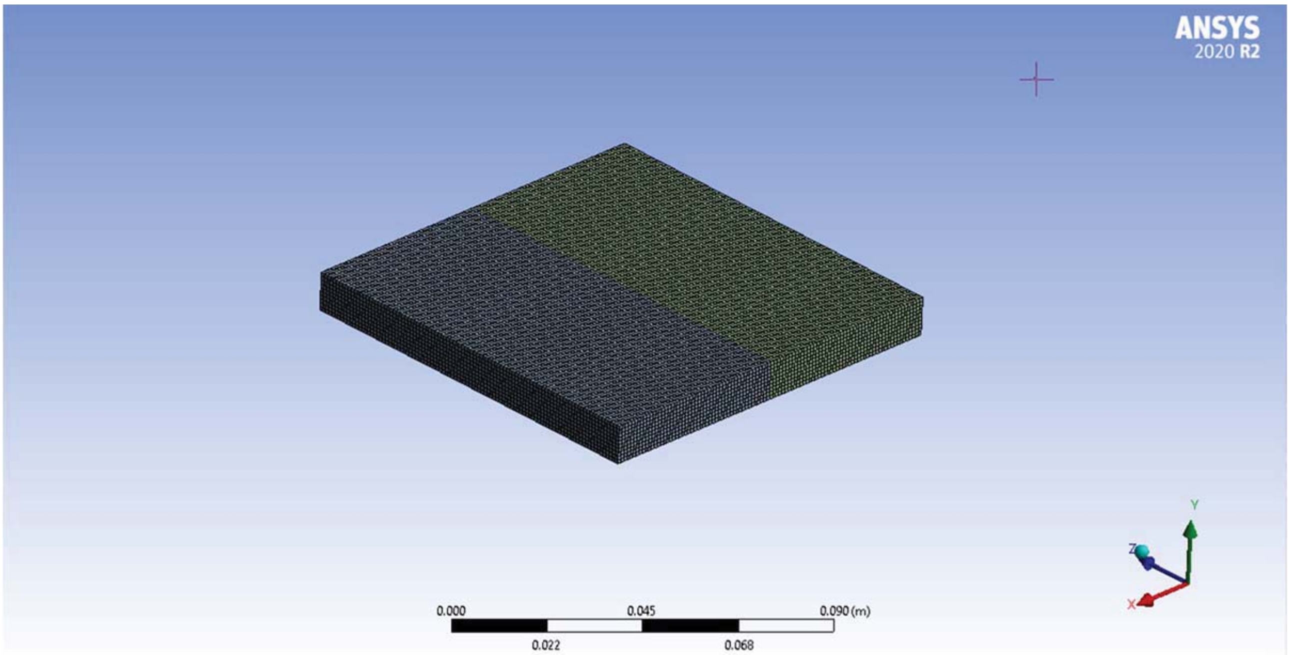


Fig. 2. Mesh geometry

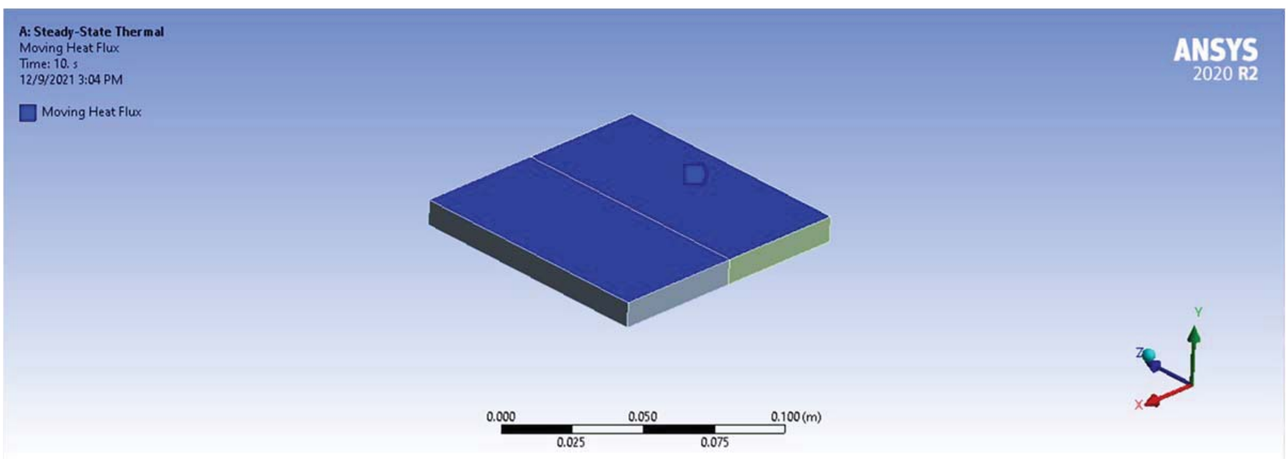


Fig. 3. Moving heat (laser)

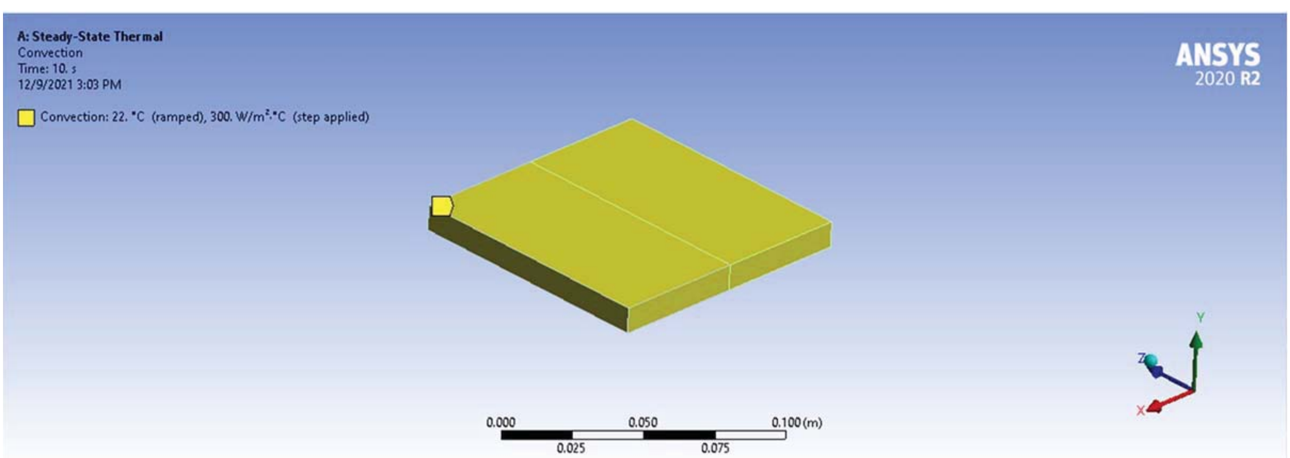


Fig. 4. Convection

Table 1

Mesh independency

Case	Element	Node	Temperature (°C)
1	41057	106367	1390.6
2	60528	215457	1365.7
3	83462	347904	1360.9
4	100000	439642	1360.8

Table 2

Properties of materials

Property	Unit	Steel	Al_2O_3	TIC
Density	kg/m^3	7835	3980	4940
Coefficient of thermal expansion	1/K	0.0000145	0.0000109	0.0000077
Young's modulus	MPa	210000	413000	451000
Poisons ratio	–	0.3	0.3	0.19
Tensile ultimate strength	MPa	1990	665	258
Thermal conductivity	W/m.K	28.6	38.5	30.93
Melting point	K	1745	2369	3338
Property	unit	steel+Al_2O_3 0.3	steel+Al_2O_3 0.6	steel+Al_2O_3 1
Density	kg/m^3	7823.435	7811.87	7796.45
Coefficient of thermal expansion	1/K	1.44892E-05	1.44784E-05	0.000014464
Young's modulus	MPa	210609	211218	212030
Poison's ratio	–	0.3	0.3	0.3
Tensile ultimate strength	MPa	1986.025	1982.05	1976.75
Thermal conductivity	W/m.K	28.6297	28.6594	28.699
Melting point	K	1746.872	1748.744	1751.24
Property	unit	steel+TIC 0.3	steel+TIC 0.6	steel+TIC 1
Density	kg/m^3	7826.315	7817.63	7806.05
Coefficient of thermal expansion	1/K	1.44796E-05	1.44592E-05	0.000014432
Young's modulus	MPa	210723	211446	212410
Poison's ratio	–	0.29967	0.29934	0.2989
Tensile ultimate strength	MPa	1984.804	1979.608	1972.68
Thermal conductivity	W/m.K	28.60699	28.61398	28.6233
Melting point	K	1749.779	1754.558	1760.93

Where heat transfer by convection was used for the rest of the surfaces with an external temperature of 22 °C and a heat transfer coefficient of 300 W/m°C to quickly get rid of the heat acquired by the metal through the used laser, where the properties of the laser used were as follows Table 3.

After the completion of the thermal conditions, the mechanical conditions are added, as the heat creates these stresses, and the ends of the geometry must be fixed to see the distortions and stresses that result in the process of comparing the concentrations of nanomaterials and their effects on the material Fig. 5.

Table 3

Laser processing parameters

Index	1
Radius of the beam	0.005 m
Velocity	0.01 m/s
Source power intensity	10000000 W/m^2
Start time	0 s
End-time	10 s
Number of segments	200

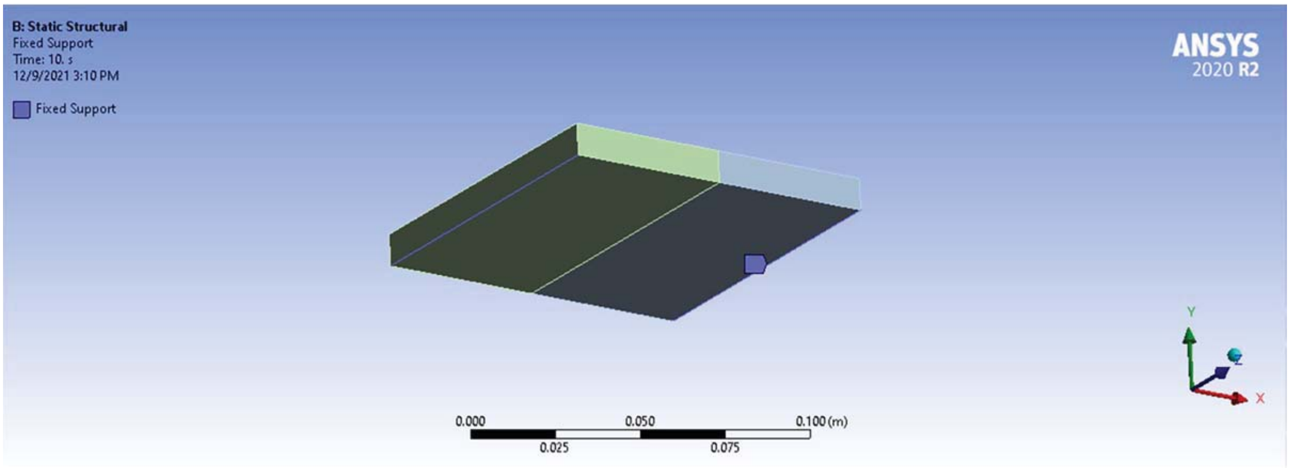


Fig. 5. Fixed edge

Governing equations.

The general balance conditions for straight primary static investigation namely:

$$[K]\{u\}=\{F\}, \tag{1}$$

or

$$[K]\{u\}=\{F^a\}+\{F^r\}, \tag{2}$$

where

$$[K]=\sum_{m=1}^{N}[K_e], \tag{3}$$

$\{u\}$ – nodal dislodging vector;

N – number of elements;

$[K_e]$ – component solidness framework (depicted in Element Library) and (might incorporate the constituent stress firmness grid (portrayed in Stress Stiffening);

$\{F^r\}$ – response load vector $\{F^a\}$, the complete applied burden vector, is characterized by:

$$\{F^a\}=\{F^{nd}\}+\{F^{ac}\}+\sum_{m=1}^{N}\left(\{F_e^{th}\}+\{F_e^{pr}\}\right), \tag{4}$$

where $\{F^{nd}\}$ – applied nodal load vector;

$\{F^{ac}\}=-[M]\{a_c\}$ – acceleration load vector;

$$[M]=\sum_{m=1}^{N}[M_e]= \text{total mass matrix;}$$

$[M_e]$ – component mass grid (portrayed in Derivation of Structural Matrices);

$\{a_c\}$ – all out speed increase vector (characterized in (Acceleration Effect));

$\{F_e^{th}\}$ – component warm burden vector (portrayed in Derivation of Structural Matrices;

$\{F_e^{pr}\}$ – component pressure load vector (portrayed in Derivation of Structural Matrices).

To summarize the heap vectors in equation (2) take into consideration a one-component section model, stacked exclusively via its weight, utilized and response load vectors. Note that the lower utilized gravity load is used straightforwardly for the forced dislodging and consequently causes no strain; all things considered, it is added to the response load vector similarly to the higher applied gravity load. Additionally, if the solidity for a specific DOF is zero, any applied loads on that DOF are disregarded.

The general conditions for direct first request frameworks are as old as a straight primary static investigation. though, is the all-out coefficient lattice (e. g., the conductivity network in a warm examination) and {u} is the nodal DOF esteems. $\{F^a\}$, the all-out applied burden vector, is described via:

$$\{Q^a\}=\{Q^{nd}\}+\sum_{m=1}^{N}\{Q_e\}. \tag{5}$$

Mechanics:

– $\{u\}$ – deformation;

– $\{F^{nd}\}$ – force;

– $\{F_e\}$ – reaction force.

Thermal:

– $\{T\}$ – temperature;

– $\{Q^{nd}\}$ – heat flow generation convection;

– $\{Q_e\}+\{Q^g_e\}+\{Q^c_e\}$ – heat flux heat.

The classification relates the terminology utilized in the Derivation of Heat Flow Patterns and the Derivation of Electromagnetic Patterns for warm, attractive, Nomenclature of Coefficient Matrices, for a more definite classification portrayal.

5. Results of laser wilding

5. 1. Thermal stress and its effect on steel

With the use of lasers in the process of heat treatments, the effect of these properties of the used laser, its thermal effect, and the mechanics of the body's illness used in this simulation was shown Fig. 6.

Temperature gradients with time appear, and let's note the behavior of the laser on the metal piece of steel. The temperature gradients and the location of the laser with time, which is 10 s.

Through the previous Fig. 7, observe the temperature distribution that shows the movement of the laser with time, where the temperature in the 10 s reached 1360.8 Celsius.

Fig. 7 shows the deformations and stresses resulting from the thermal effect of the laser, where the distortion reached 0.4126 mm and the stress value reached 10.435 GPa, which is the highest value reached compared to after adding nanomaterials.

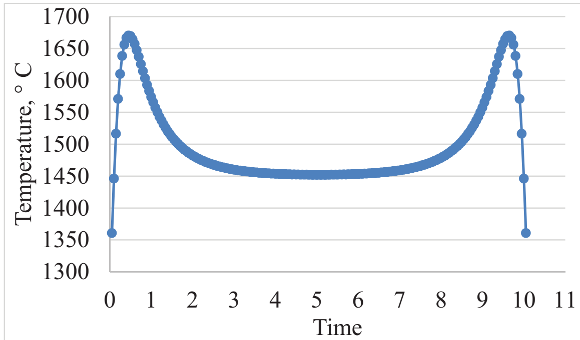
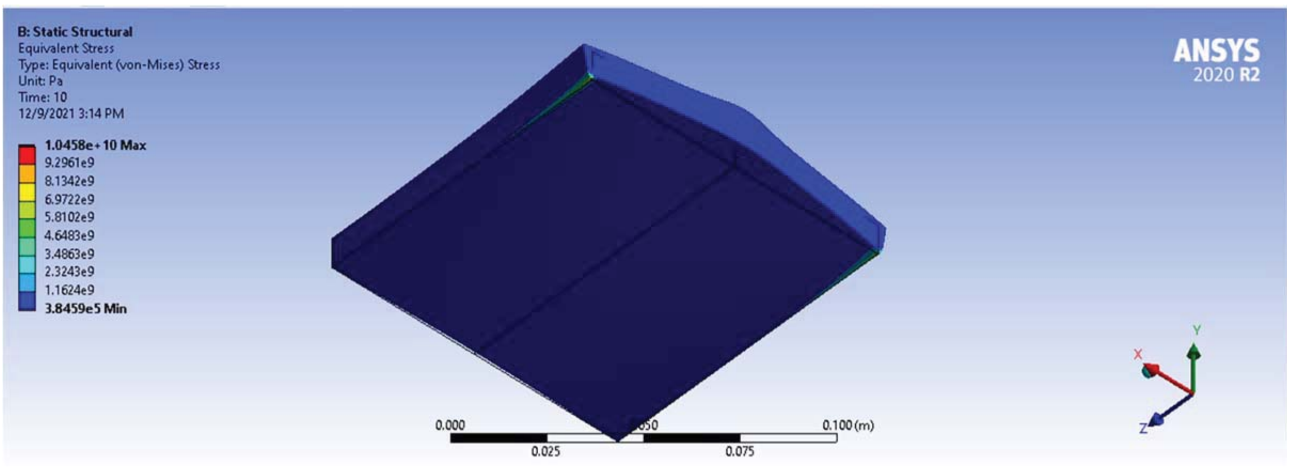
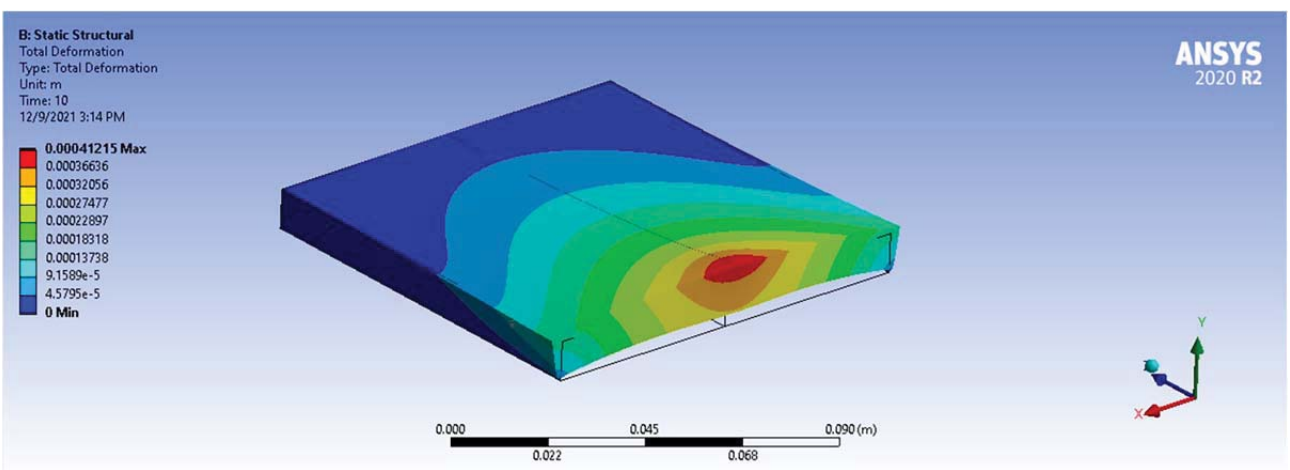


Fig. 6. Maximum temperature on geometry



a



b

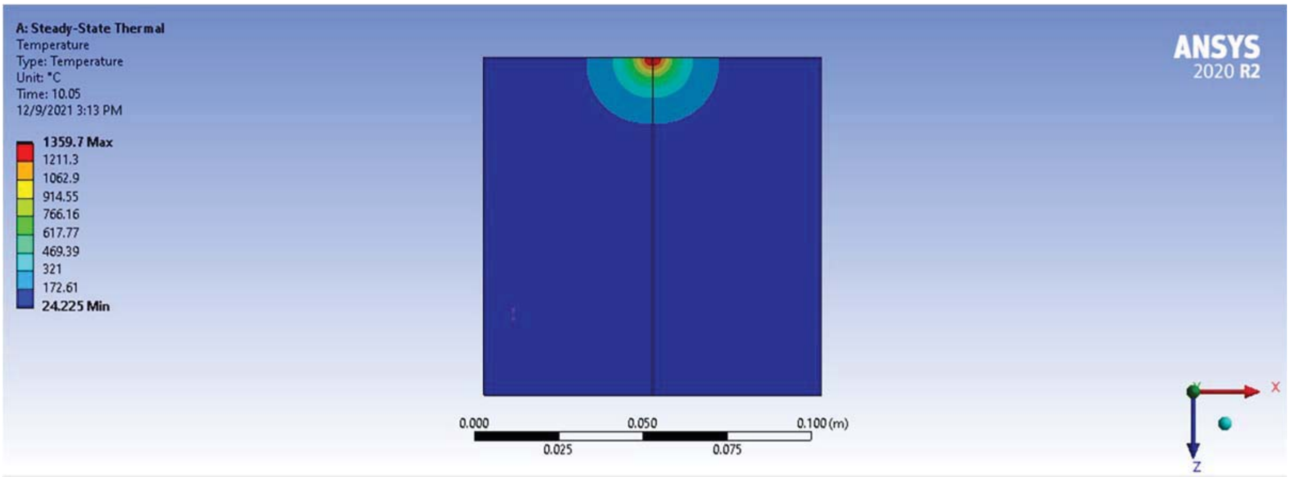
Fig. 7. Gradient of steel: *a* — stress gradient; *b* — deformation gradient

5. 2. The effect of nanomaterials on thermal and mechanical stresses

In improving thermal treatments, it is necessary to resort to nanomaterials that can improve the characteristic structure of the material, whether in various types of stresses or conditions to which it is exposed Fig. 8.

Fig. 8, 9 show the effect of nanomaterials on heat transfer and retention, and this indicates the ability of nanomaterials to change the thermal properties of the base material, which is steel, where the temperatures of Al_2O_3 and tic reach (1375.2 and 1359.9 degrees Celsius, respectively. This is where the effectiveness of the nano-tic material in terms of its heat reception is shown.

Fig. 10, 11 show the effectiveness of nanomaterials in mechanical stresses, where the materials affect the strength and durability of the materials by increasing the percentages in the mechanical properties.



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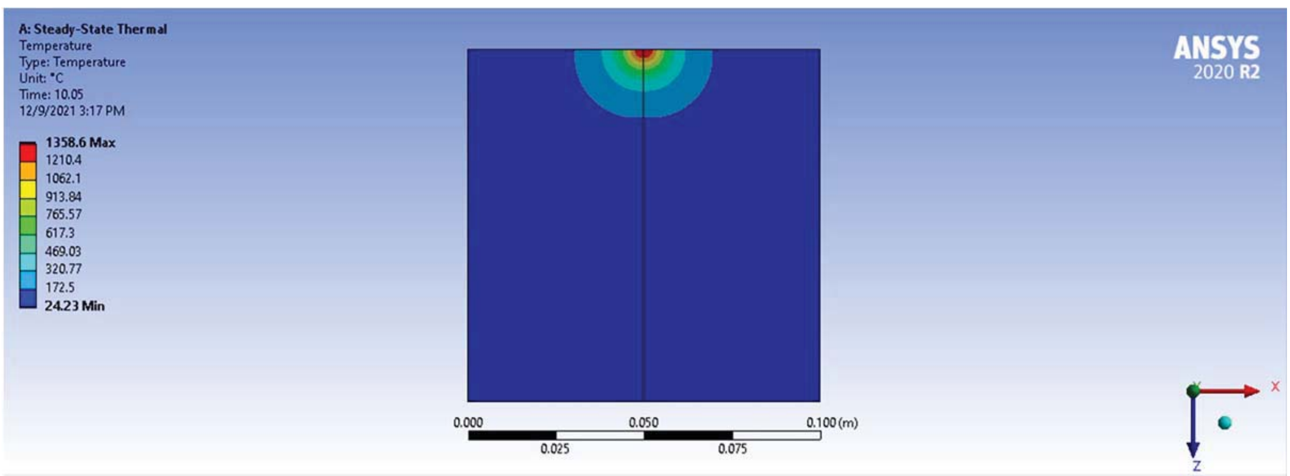

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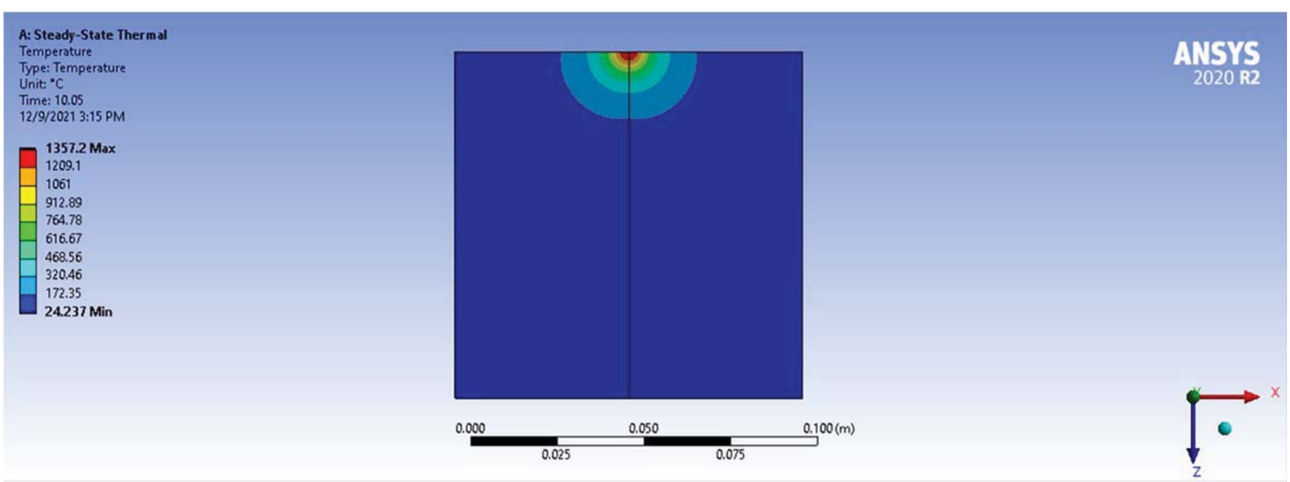
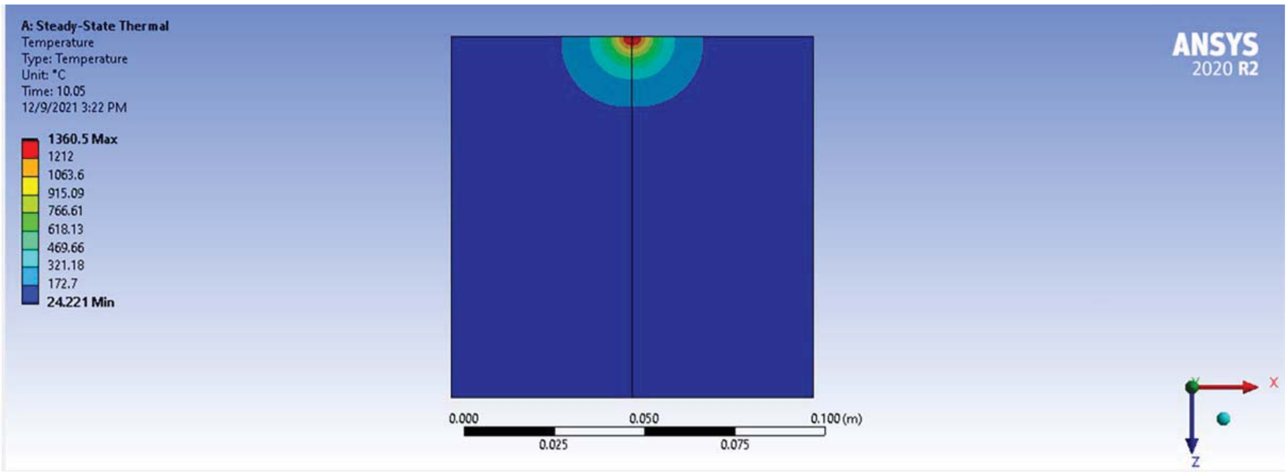
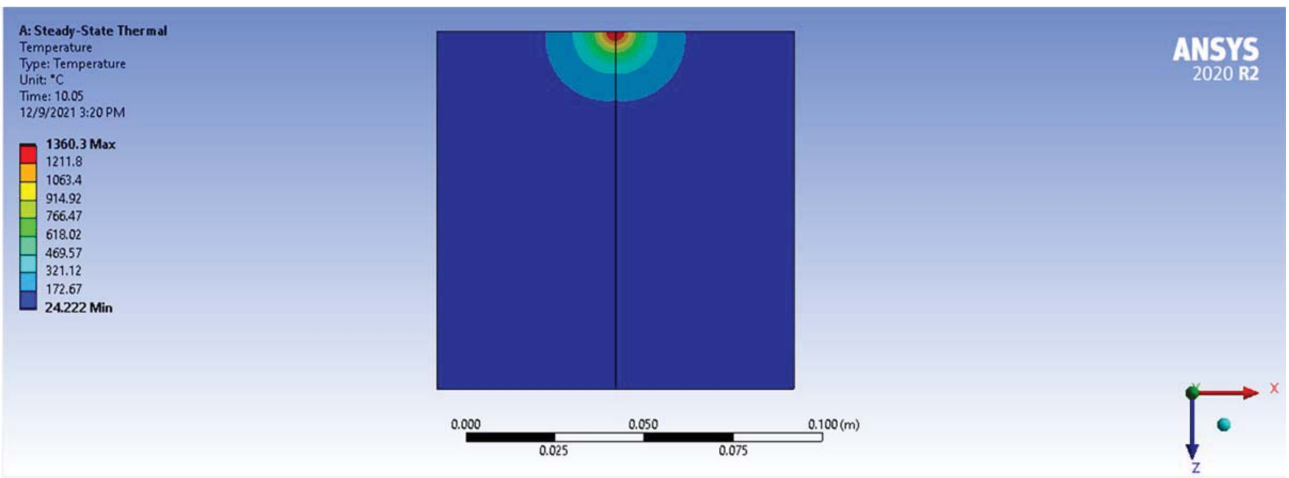


c

Fig. 8. Thermal effect after adding Al_2O_3 with concentrations: *a* – 0.3 wt%; *b* – 0.6 wt%; *c* – 1 wt%



a



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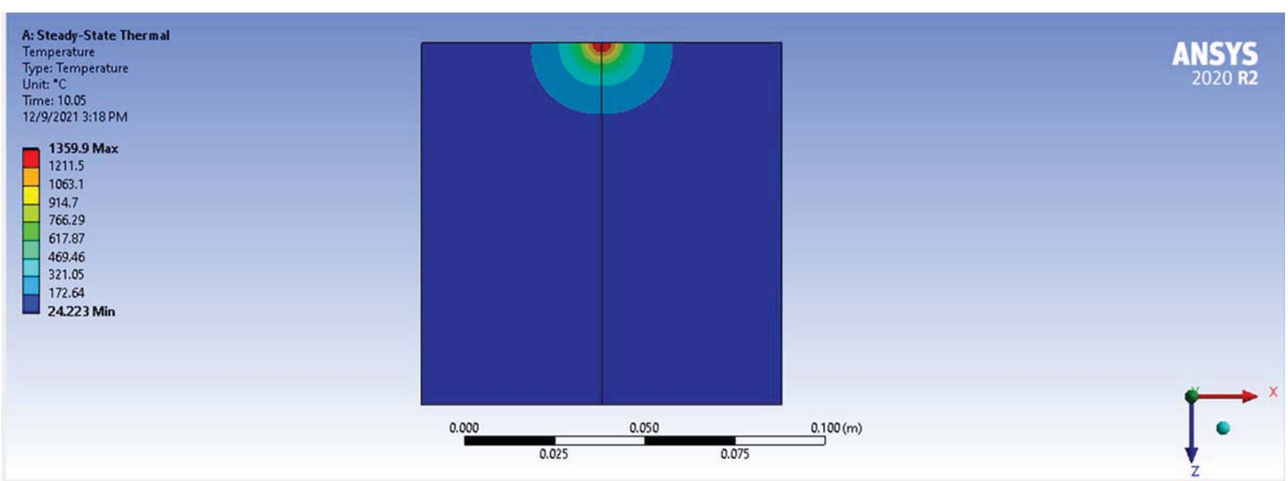
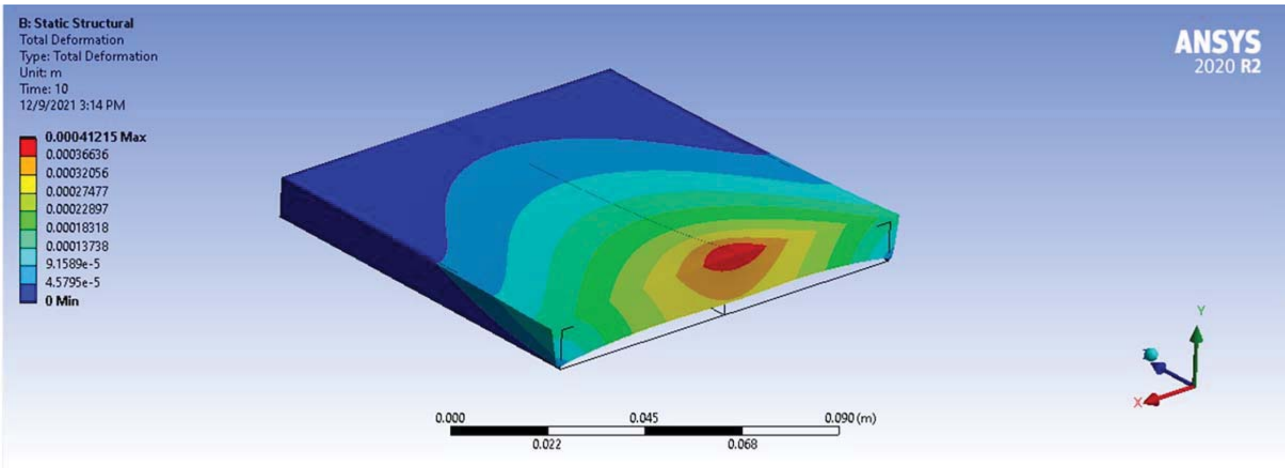
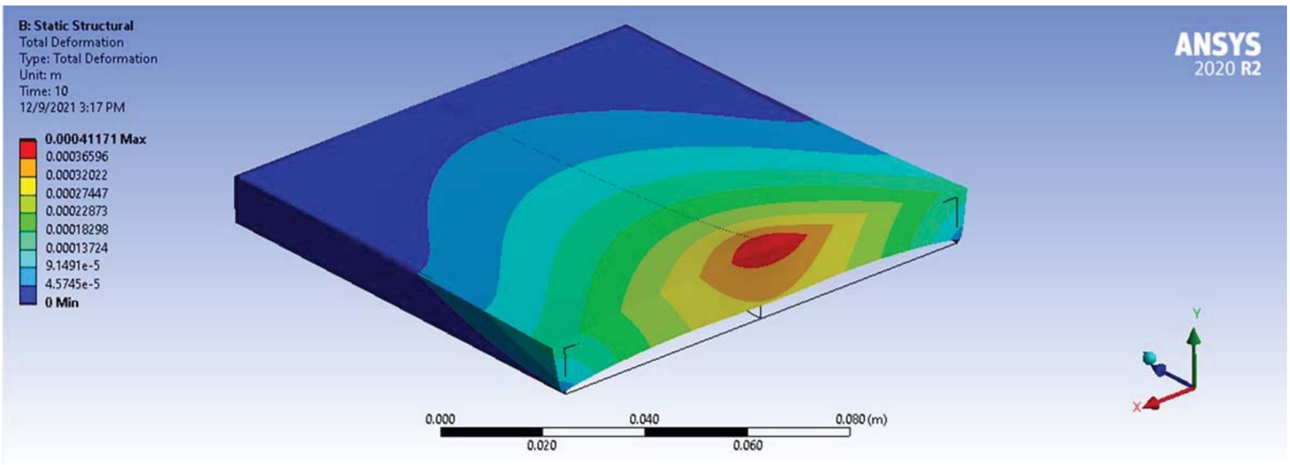


c

Fig. 9. Thermal effect after adding Tungsten inert gas with concentrations: *a* – 0.3 wt%; *b* – 0.6 wt%; *c* – 1 wt%



a



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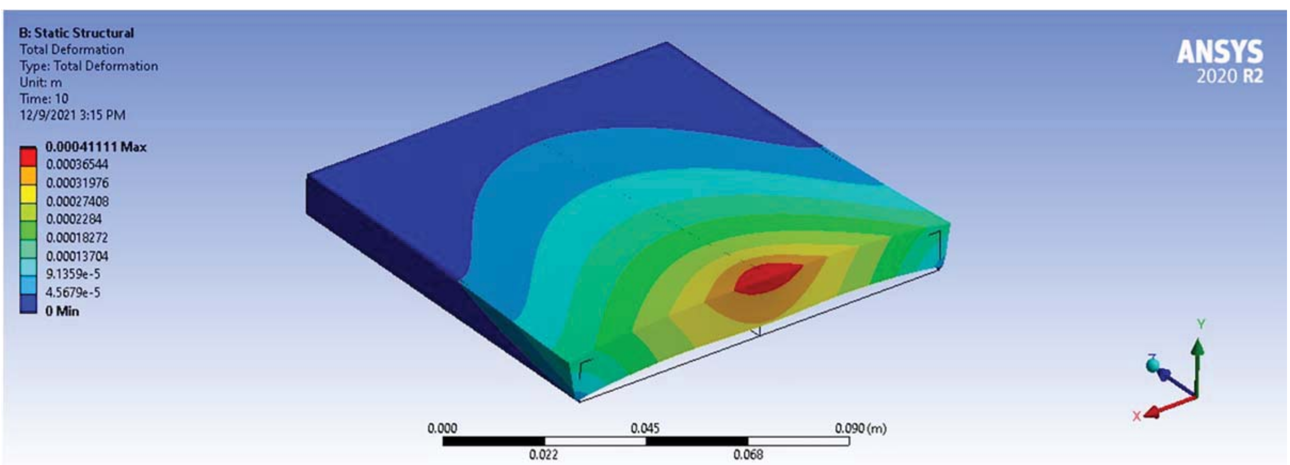
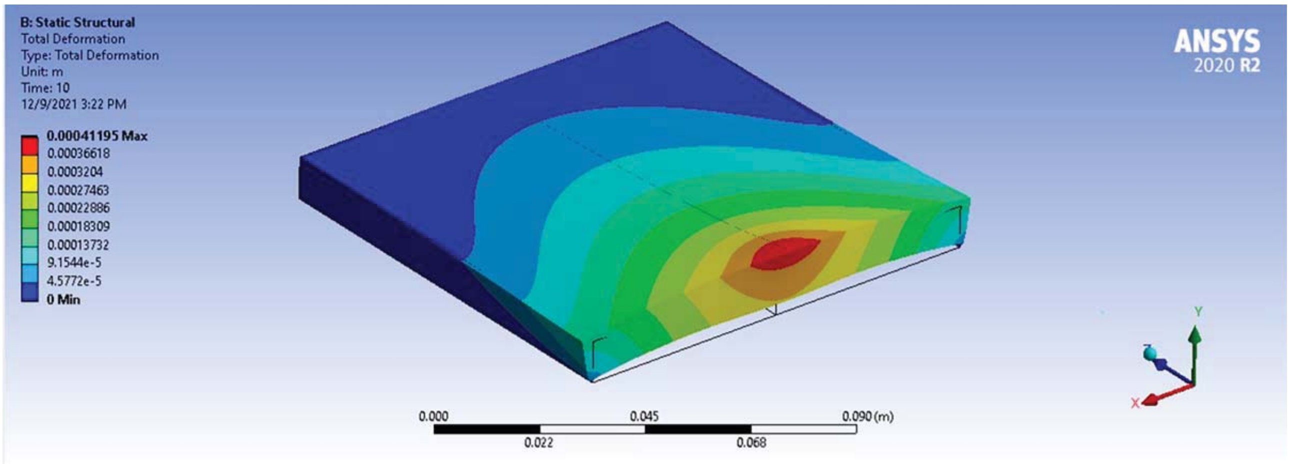
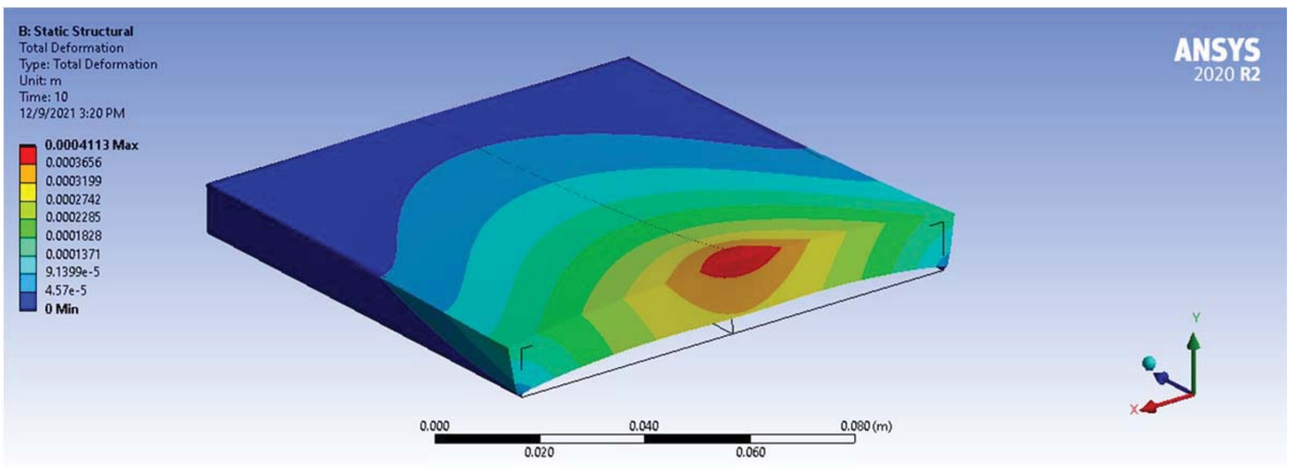


c

Fig. 10. Deformation after adding Al_2O_3 with concentrations: *a* – 0.3 wt%; *b* – 0.6 wt%; *c* – 1 wt



a



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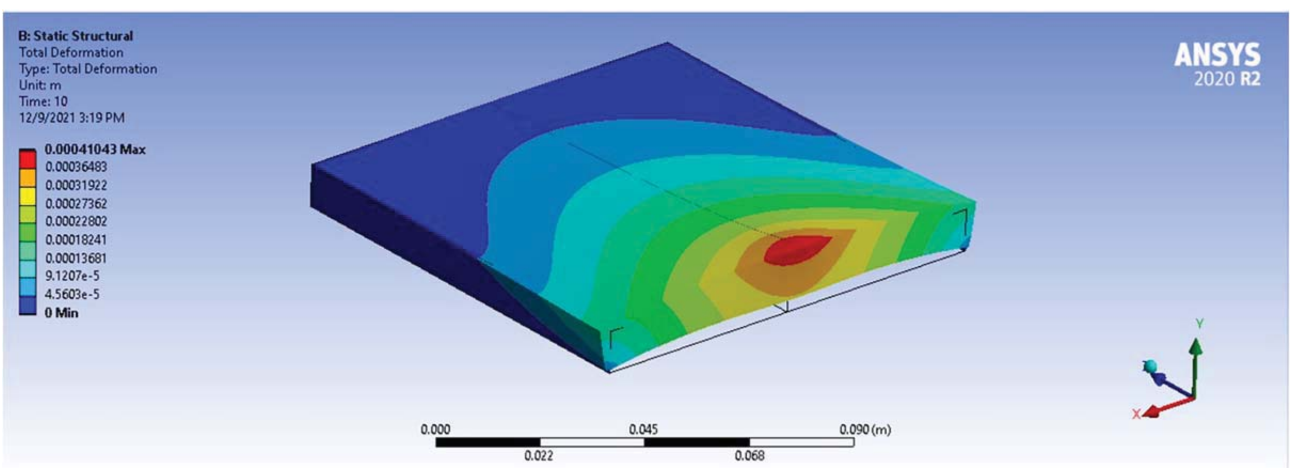

c

Fig. 11. Deformation after adding Tungsten inert gas with concentrations: *a* – 0.3 wt%; *b* – 0.6 wt%; *c* – 1 wt%

Therefore, it appears that the nanomaterials tic at a concentration of 1 wt% formed the best structure of the material and obtained the least distortion during the laser heat applied, where the value of the distortion is 0.4104 mm, which is less than that of the AL_2O_3 nanomaterial.

6. Discussion of effect of fins characteristics

Fig. 6 appears the temperature gradients with time, and noted the behavior of the laser on the metal piece of steel. The temperature gradients and the location of a laser with time, which is 10 s. After adding nanomaterials to a laser beam, the distortion reached 0.4126 mm and the stress value reached 10.435 GPa, which is the highest value reached compared to after adding carbon nanotubes. Fig. 8 shows the deformations and stresses resulting from the thermal effect of the laser and how this affects the thermal properties of the base material, which is steel. The temperatures of Al_2O_3 and TIC reach (1375.2 and 1359.9 degrees Celsius) where the effectiveness of nano-tic material in terms of its heat reception is shown. Nanomaterials TIC at a concentration of 1 wt % formed the best structure of the material and obtained the least distortion during the laser heat applied, where the value of the distortion is 0.4104 mm, which is less than that of the Al_2O_3 nanomaterial.

The process of simulating nanomaterials for surfaces when welding is somewhat new with respect to the previous researchers [1–13]. The field of application of the results is in welding operations as well as improving the mechanical properties of metals during the welding process.

The limitations used in the work is the imposition of two pieces of metal that can be welded by a variable HEAT FLUX, as in the real case it is a laser and a metal that takes a complex geometry.

There are a lot of heat losses that can change the shape of the thermal gap of the laser and the inability to take different types of metals because there is no ability to analyze them due to the difficulty of obtaining large computers.

Multiple geometries of welding pieces can be taken to see their impact on the welding process, as well as different types of nanomaterials may be used, which greatly affect heat.

7. Conclusions

1. In this study, let's observe the behavior of a laser on a metal piece of steel. the temperature gradients and the location of the laser with time, which is 10 s. The distortion reached 0.4126 mm and the stress value reached 10.435 GPa. This is the highest value reached compared to after adding nanomaterials.

2. Nanomaterials Al_2O_3 and tic at a concentration of 1 wt% formed the best structure of the material and obtained the least mechanical stresses thus minimum deformations during the laser heat applied, where the value of the deformations is 0.4104 mm, which is less than that of the Al_2O_3 nanomaterial.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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The study was performed without financial support.

Data availability

Data will be made available on request.

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