THE ANNALS OF "DUNĂREA DE JOS" UNIVERSITY OF GALAŢI
FASCICLE V, TECHNOLOGIES IN MACHINE BUILDING,
ISSN 1221- 4566, 2017

NUMERICAL EVALUATION OF THE PRESSURE FORCE IN BUTT COLD WELDING FOR A RANGE OF ALUMINUM BARS DIAMETERS USING A 2D AXISYMMETRIC FEM MODEL

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ABSTRACT

Butt cold welding of aluminum bars or wires is a process with several important applications. The purpose of this paper is to create a numerical model (a two-dimensional FEM model) of this process and to estimate numerically the pressure force required to obtain the join between two bars or two wires, based on the published information from the practice of butt cold welding.

For bars in a range of diameters of 5mm up to 30mm were established the relationships between the diameters of aluminum bars on the one hand and the minimum pressure force, the displacement of the clamping die, and the plastic strain energy stored in the aluminum bars on the other hand.

The FEM model is an axisymmetric one as the process is axisymmetric also.

KEYWORDS: butt welding process, 2D FEM model

1. INTRODUCTION

Cold welding is a form of solid phase welding, which is carried out at ambient temperatures. Many wire and cable manufacturers prefer a welding process that is a 'green' one and that enables to join non-ferrous materials without heat, saving both money and materials [2].

This process requires important materials deformation degrees (usually over 70%), obtained by using high pressure which can exceed ten times the maximum yield strength of the material [1].

Cold pressure welding can be achieved mainly by two methods: spot welding and butt welding [1]. In both cases, can be obtained a welded joint. Wires and bars can be joined using butt cold welding. By using cold welding we can bond rods of 5mm up to 30mm diameter or wire of 2mm up to 6.5mm diameter [2].

Easily deformable metals as aluminum or copper can be coldly welded, but the process can be also achieved between other metals (aluminum-stainless Steel, aluminum-titan and between theirs alloys) [1].

When the material is inserted in the die, the material is gripped by the die and fed forward. As they are pushed against each other, the two opposing faces of the material are stretched and enlarged over their entire surface area [2] (see the main forces in butt cold welding process in Figure 1).

In principle, the cold welding is technologically obtained under the action of the adhesion force at the atomic level and of the atomic diffusion [2]. To obtain this bond (using butt cold welding) it is necessary a minimum level of deformation of the basic material; e.g. the minimum deformation level for gold is 35%, for silver is 50%, for aluminum is 60%, for copper 90% and for iron is 81% [2]. The level of plastic deformation by cold welding is estimated by surface increasing in case of butt cold welding.

The minimum level of plastic deformation for the butt cold welding must ensure an increase of deformed surface of minimum 160% for the aluminum and minimum 80% in the case of copper [3]. The force required to obtain joining between two bars (the pressure force) induces a pressure of 700-800 N/mm2 for aluminum and 2000-2500 N/mm^2 for copper [3]. The gripping force is about 50% greater than the pressure force [3].

2. TWO DIMENSIONAL AXISYMMETRIC FEM MODEL OF THE BUTT COLD WELDING

The FEM model of the cold welding process of aluminum bars was created in Ansys Workbench in the Static structural module.

The stress-strain curve of 99.5% aluminum is represented in Fig. 2. The Young modulus is 6.9e 1010 N/m2 and the Poisson ratio is 0.3.

The geometry of the model is represented in Figure 3; a symmetry region is defined as in the Figure 3.

The model has 51609 nodes and 17012 quadrilateral elements; the size of side of elements on the aluminum bar is of 0.0001m (see the mesh in the Figure 4).

The boundary conditions applied are represented in Figure 5 (prescribed displacement of the system bar-clamping die). The value of the displacement correspondd to the level of plastic deformation of aluminum bar to ensure the cold welding.

The results presented in Figure 6 (von Mises stress) and Figure 7 (equivalent plastic strain) correspond to the 10mm diameter of aluminum bar.

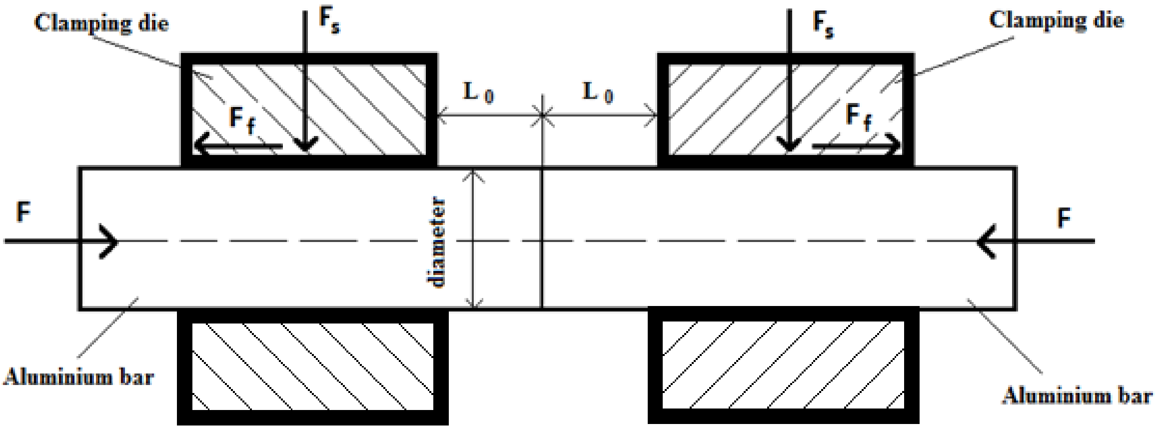

Fig. 1: Forces acting in butt cold welding process (F-the pressure force, F_s - the radial clamping force F_f- the frictional force); L_0=diameter/2.[1],[3]

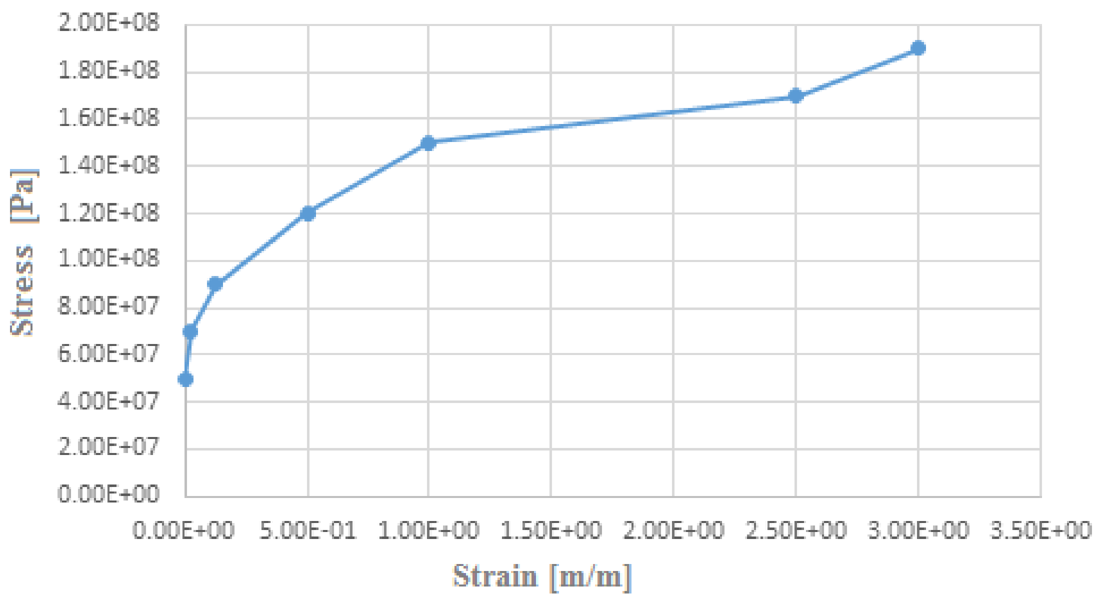

Fig. 2: The stress-strain curve of 99.5% aluminum

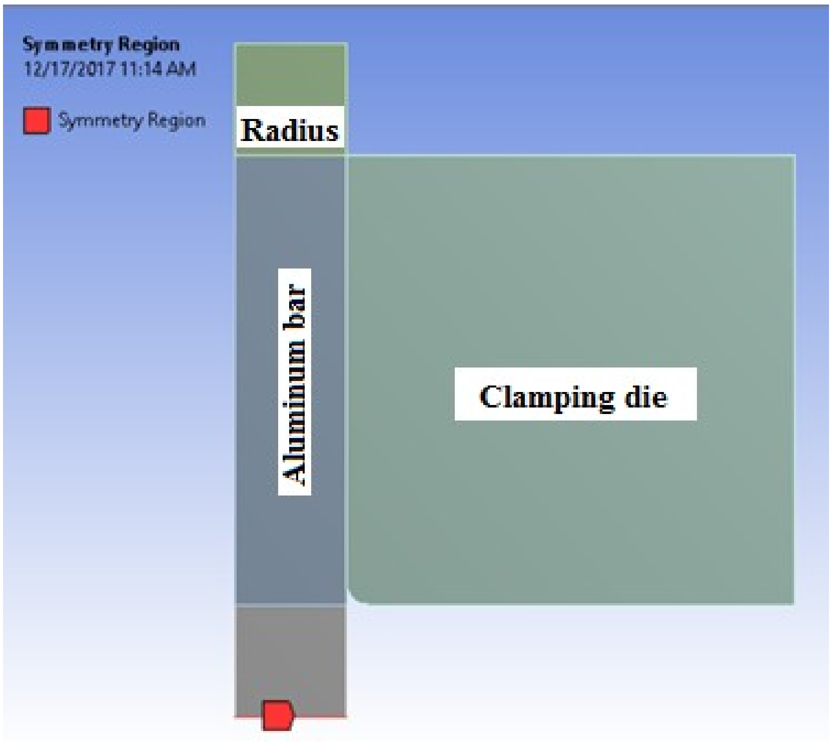

Fig. 3: The geometry of axisymmetric model

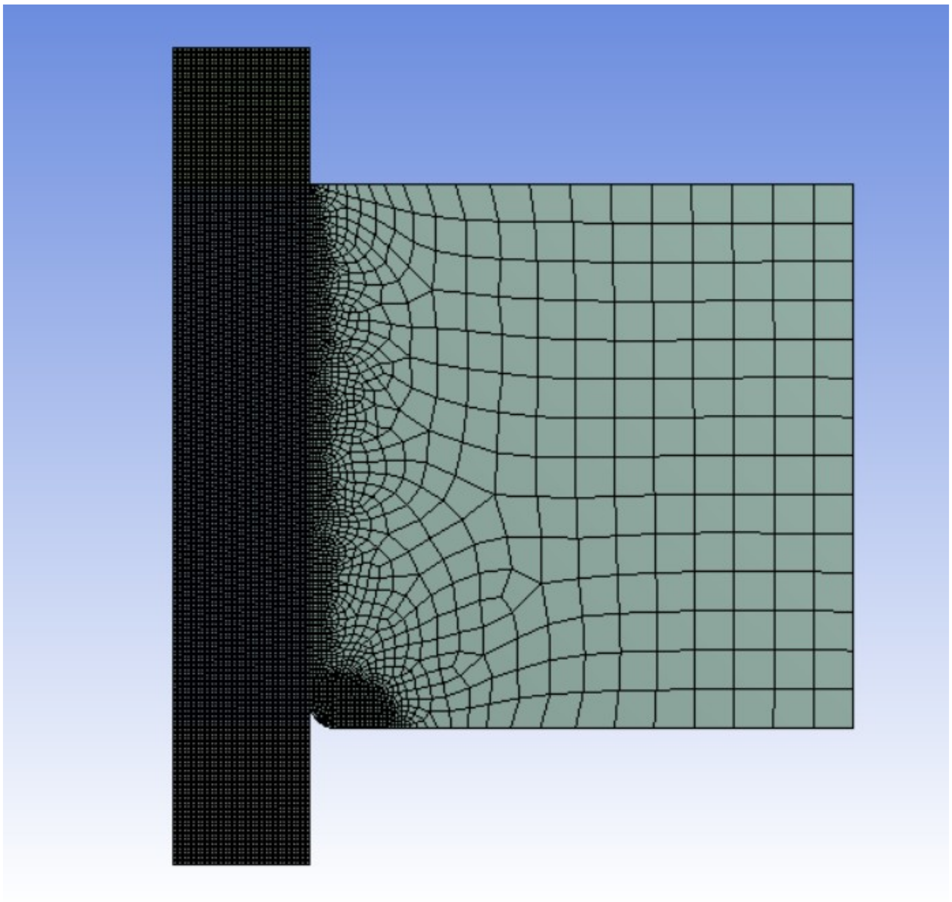

Fig. 4: The mesh on the aluminum bar and on the clamping die

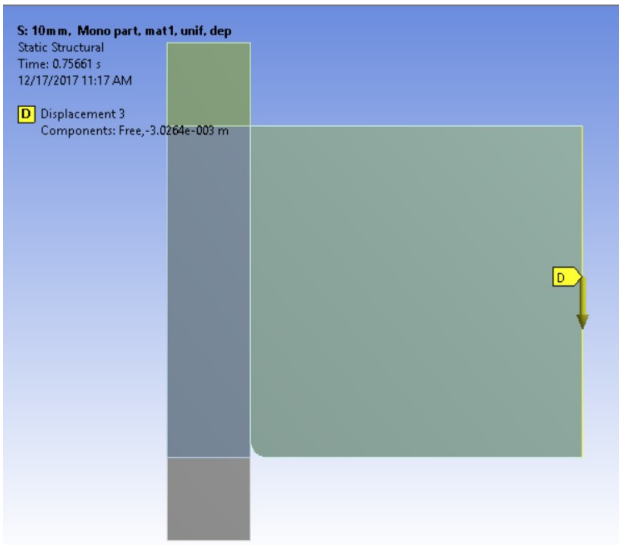

Fig. 5: The boundary conditions (prescribed displacement)

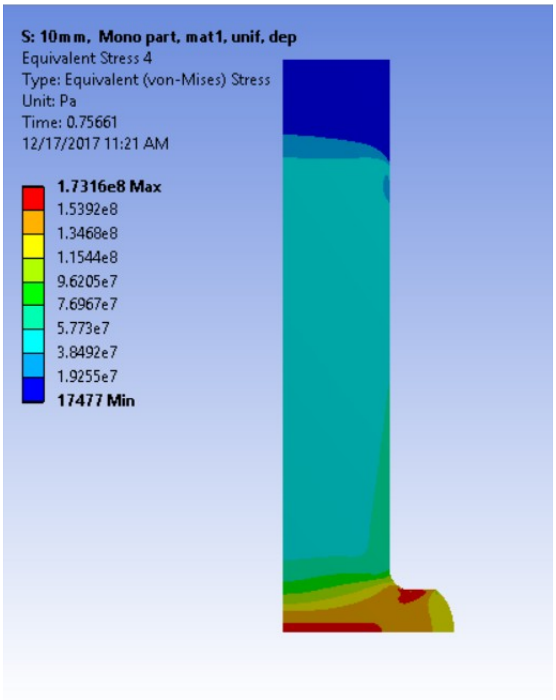

Fig. 6:The distribution of von Mises Stress in the aluminum bar

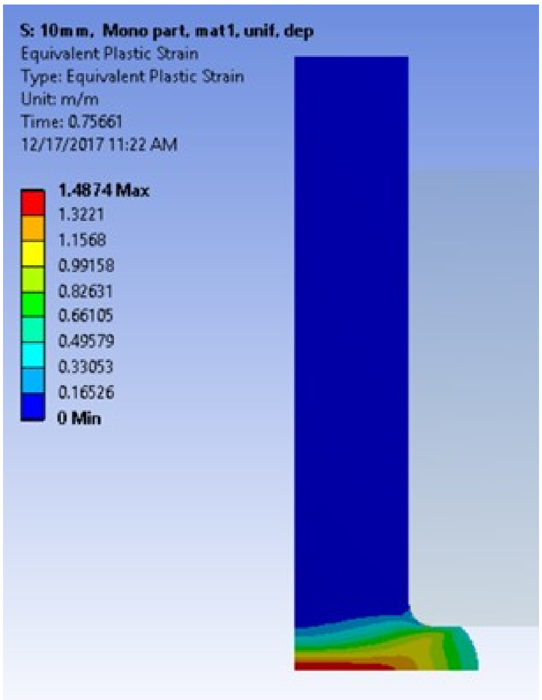

Fig. 7: The distribution of the equivalent plastic strain in the aluminum bar

3. CONCLUSIONS

The calculations were made for a range of aluminum bars diameters from 5mm to 30mm. All the models can be obtained using a scaling procedure.

The pressure force variation is represented in the Fig. 8. The pressure force is proportional to the square of the bar diameter and can be approximated with the relationship (1). The pressure force [KN] = D^2 [mm^2] * 0.3702351 (1)

The regression curve of the pressure force variation vs the square of bar diameter is represented in Fig. 9.

The variation of the prescribed displacement required to weld the aluminum bar in the specified range of diameters is represented in the Fig. 10. The prescribed displacement is proportional to the diameter of aluminum bar. The prescribed displacement can be approximated with the relationship (2):

The prescribed displacement [mm] = D [mm] * 0.302934374 (2).

The variation of strain energy with the aluminium bar diameter is represented in Fig. 11.The strain energy E is proportional to the cube of the bar diameter and can be approximated with the relationship (3):

The strain energy E [J] = D^3 [mm^3] * 0.04317218. (3)

The regression curve of the strain energy variation vs the cube of bar diameter is represented in Fig. 12. The numerical results obtained for pressure force for a few aluminum bars diameters match with those resulting from the welding practice from reference [1] and [3]. So, the numerical results and the relationships obtained using FEM model can be useful in cold welding practice of aluminum bars.

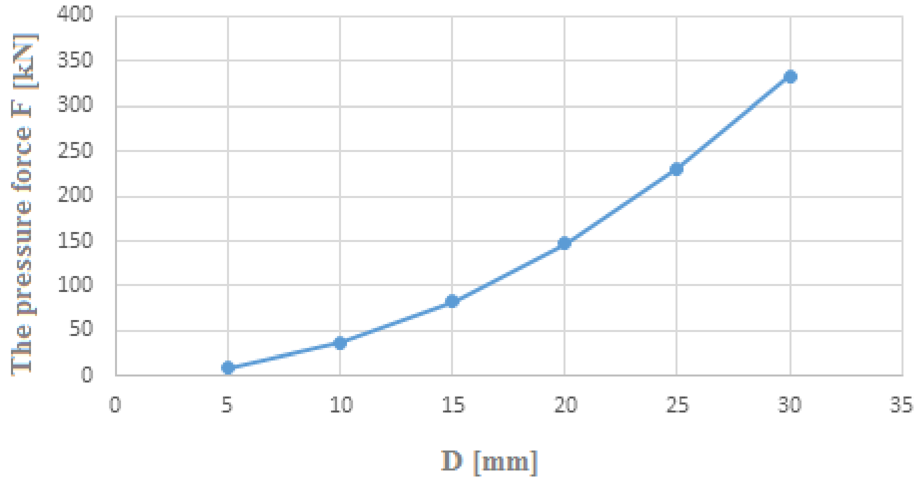

Fig. 8: The variation of pressure force as a function of the aluminum bar diameter

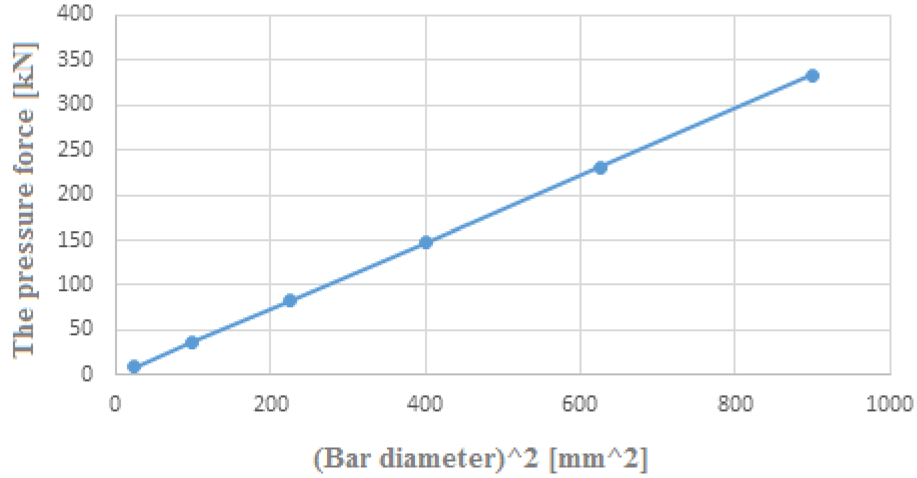

Fig. 9: The regression curve of pressure force vs the square of aluminum bar diameter

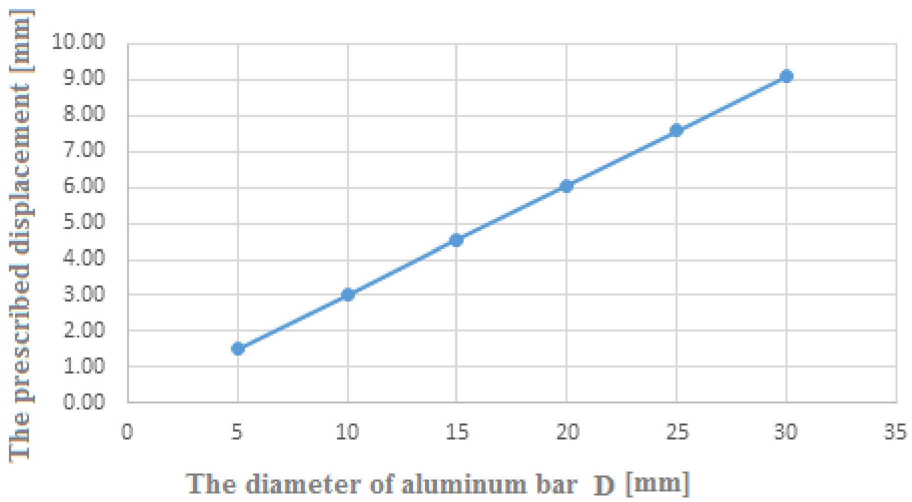

Fig. 10: The variation of the prescribed displacement as a function of the aluminum bar diameter

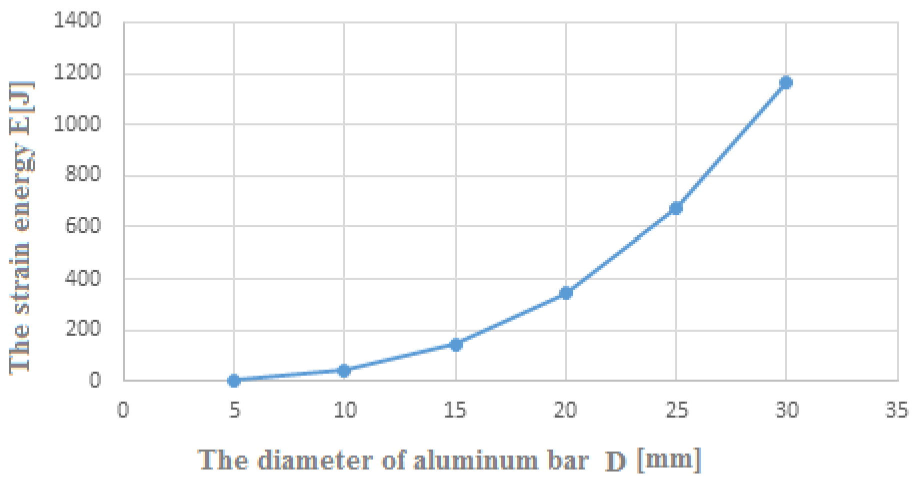

Fig. 11: The variation of strain energy as a function of the aluminum bar diameter

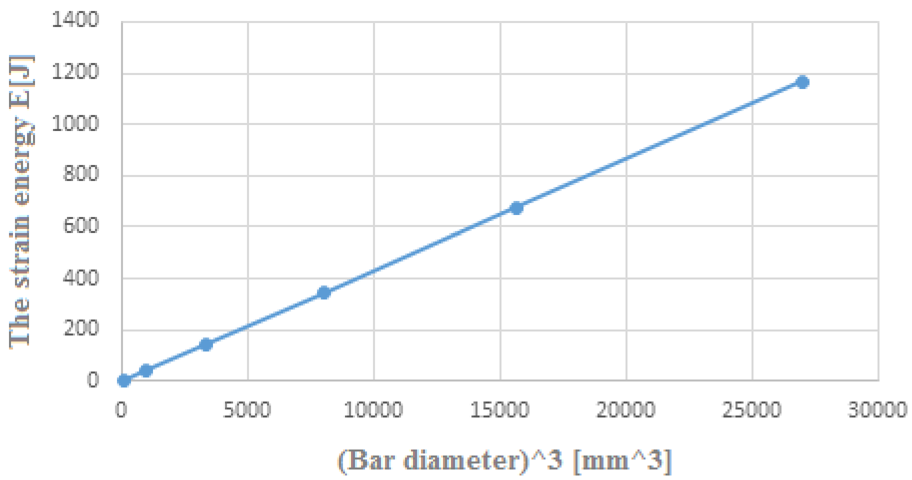

Fig. 12: The regression curve of strain energy vs. the cube of aluminum bar diameter

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[4] **Ansys Workbench documentation.**