http://ijea.jctjournals.com/ ISSN(ONLINE):2320 – 0804

Volume-11, Issue-8, August, 2022
International Journal ofEngineering Associates (IJEA)
Page Number: 01-06

Parametric Performance Analysis of the Wire Bending Mechanism By Using the Finite Element Method And Regression Analysis :- A Review

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Abstract*— Wire bending mechanism is a mechanical technique with the help of induced plastic deformation to transform rods into arbitrarily shaped thin structures. This technique of wire shaping metal parts is faster and cheaper than other techniques such as 3-D printing, in comparison it is more accessible to the general public. This is why the wire bending mechanism has the potential to become an alternative to 3-D printing. One of the major advantages of the wire-bending mechanism is the wire structure that exhibits far greater strength and fatigue properties than 3-D printed parts. The objective of this work is to study the performance of the Wire Bending Mechanism under the application of dynamic load by using the CATIA 5.1, ANSYS 2020 R1 and MINITAB 19. In this manner, finite element analysis and regression analysis were performed. The results of ANSYS were used in MINITAB to generate the regression model for forecasting of the performance. It was found that the simulation of full WireBending Mechanism process is too time consuming to be used in engineering work. However, Total Deformation, Directional Deformation, Force Reaction, Equivalent Stress, Equivalent Elastic Strain and Pressure can successfully be predicted with simplified models.

***Keywords*—Wire, Bending, Regression, ANSYS, MINITAB, Strain, Pressure, etc…**

I. INTRODUCTION

The bending head with an integrated wire cutting mechanism is provided with a simplified wire bending mechanism. The bending head has an inner part, with a wire bending channel in the inner part; And an outer part, composed of one or more bending rollers or pins in the outer part, and a cutting edge to separate the bent wire in the finished cut-off section. The outer body of the bending head is rotatable about the inner body to produce the bending force above the wire so that the bending pin or roller is able to bend the wire around the inner body.

In addition, the outer body is moveable from one position to another with a cutting tool installed to connect and close the wire. Immediately deformed materials are used for bent wire structures, must be lightweight and durable to withstand the bent force above it, and can bend easily without spreading any cracks in the surface. We present here a computational simulation of the wire bending technique to understand the bending wire and we have also estimated the bending effect through the use of the bending mechanism. A simplified wire bending mechanism is provided comprising a bending head with an integrated wire cutting mechanism. The bending head having an inner portion, wherein the inner portion includes a wire bending channel; and an outer portion, wherein the outer portion includes a one or more bending rollers or pins and a cutting edge to separate the bended wire in finished cut-off section.

A. Technique of a Wire Bending

Wire bending mechanism is a mechanical technique to change the rods into arbitrarily shaped slender structures with the help of induced plastic deformations. This technique of wire shaping metal parts is fast and inexpensive, compare to other techniques like 3-D printing, also comparatively it is more accessible to the general public. That's why Wire bending technique has the potential to become an alternative to 3-D printing [Miguel et al. 2016]. One of the major advantages of wire-bent technique is wire structure exhibits the strength and fatigue properties far greater to those of 3-D printed parts.

II. LITERATURE REVIEW

Production Oriented Design Driven by advances in digital manufacturing technologies, computer graphics techniques have made a significant contribution to production oriented design [2]. One of the central goals of this body of work has been the development of computational tools that facilitate difficult or boring design tasks. Our work shares this general objective and the calculation methodology we present is designed for manufacturing with bending machines. Unlike previous works [3; 4; 5], we aim to analyze the deformation of the wire structure and its effect on the physical properties.
Although not intended for manufacturing, [6] we propose an image-based reconstruction of wire structures whose results we use as input for our study. The design of metamaterials [7; 8] aims to achieve the desired macroscopic behaviour by varying properties or structures at the microscopic level, relying on a single material for manufacture. We share this goal, however, this work targets solids where, instead, we refer to metal rod structures with a constant radius mechanism. Computer-aided design of traditional mechanical assemblies has become a popular subject in graphic design. The initial work includes methods that aid in understanding complex assemblies [9] and the design of mechanical toys and figures. [ten; 11; 12]. Simulation design methods [13] and corrections in link-based assemblies [13] followed.

Recent approaches help recovery [21] or reorientation [22; 23] of existing mechanisms. Our work is more closely related to the computer design of conforming mechanisms [24]. Like them, we protect ourselves from material breakage and plastic deformation with a limitation of von Mises stresses. However, while they replace traditional mechanical seals with bending and targeted 3D printing, we optimize the stiffness properties of spring-like structures created by bending wire. This new problem setup requires a new approach to design optimization, as we'll see later. Our work finds applications in the design of futuristic wire bending techniques, which complement existing tools for this exciting field. [24], for example, proposes a system allowing the mechanics of bent wire for locomotives. In our work, we take advantage of the conformity of bent steel cables to design complex and expressive kinetic characters. Compliant Rod and Cable-Actuated Structures. [26] describe a method for designing flexible reinforcing meshes, while [27] propose a system for designing structurally strong ornamental curve arrays. Like them [2], we rely on a discrete elastic thread for an accurate simulation. However, we are targeting the wire bending technique and not the three-dimensional printing methods, which leads to an unobtrusive design space that requires a different approach. For actuation, we optimize the three-dimensional forces generated by a small series of cables acting at user-specified positions with wire structures. The implementation approach we used is influenced by previous graphic studies which also used bent wires for the implementation of deformable properties [28], curved surfaces [29], physical assemblies [30] and smart toys [31]. As a common manufacturing process in the field of mechanisms, wire bending is widely used in aerospace, automotive, shipbuilding, machinery and other important fields [16]. Although China is a large producer of wire products, its technical equipment is not advanced. Semi-automatic stamping equipment is generally used to bend the wires. And for the equipment manufacturing industry, the precision requirements for intricately shaped wires are increasing as the demand for products increases [15]. All of these studies stimulate the in-depth research and development of wire bending and processing equipment, which is used to bend wire. At present, China's advanced wire forming

equipment is mainly imported from technology-developed countries such as Germany, France and Japan. While most Chinese customers abandon this route due to the extravagant price and maintenance inconvenience [20]. Currently, some Chinese manufacturers have also created such equipment, but failed to achieve improvements in these areas in terms of quality, efficiency and level of maintenance. At the same time, the high cost of production prevents it from competing in the market [14].

III. FINITE ELEMENT ANALYSIS

A. Introduction

The finite element is the problem-solving technique of the engineer and of mathematical physics. It is used fundamentally for complex geometries, loading and material properties, where the analytical solution is complex. FEA has such a great use in modern days to analyze the behaviour of the material, the purpose of safety and for an optimal design, etc. The common application of FEA is in mechanical, civil and aerospace engineering. Furthermore, the main advantages of FEA can be found in the structural analysis where stress analysis, deformation, etc. they are easily possible for complex structures such as wire cutting, wire bending, fabrication etc.

B. Methodology

The technique used to calculate the Total Deformation, Directional Deformation, Equivalent Stress, Equivalent Elastic Strain, Wire to lever Reaction Force and Wheel to Wire Reaction Force of the Wire Bending Mechanism through FEA. Using this technique, the all these parameters can be calculated in every direction when the force is applied, the basic principle of FEA is that the discretization of the wire in small parts means that the Wire Bending mechanism is first divided into an equivalent system of many smaller bodies and it says units (finite elements) in which two or more of two elements are interconnected, called nodes or nodal points. The properties and the relation of government are assumed on these elements and are mathematically expressed in terms of unknown values in a specific point of the elements called nodes.

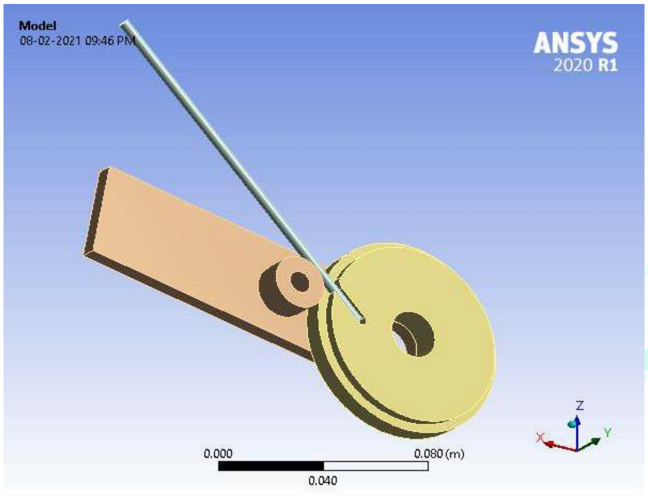

Fig.1 : Isometric view of Wire bending mechanism

IV. LINEAR REGRESSION ANALYSIS

A. Introduction

The regression model is a statistical process that allows the researcher to estimate the relationship with the linear, most variable line. This model can also be used to determine the importance of statistics, to verify if the linear relationship seen can arise from the opportunity. In the second curriculum of statistical methods, multiplexing regression was examined with relations between multiple variables. The delayed variable regression model specifies the position of a variable to a variable, and the other changes the position of a dependent variable. The independent variable can be considered as a variation on the dependent variables, where dependencies of independent variables can be used at the moment of variation. It will be seen that the investigator is no longer in charge of a reallocation of causality, included in the Regression model. If, however, the investigator likes a reason to convert a variable into a variable, then it is possible to estimate the way in which it relates to cars in the independent dependency variable. To use the regression model, the expression for the straight line checks first. This is given in the following section. Once you have found it, you do not have a formula to determine the regression line of the observed data.

B. Linear Relationships

In the regression model, there are two variables one is independent variable and the other is dependent variable X and Y variable. The two variables can be understood by a figure 4.1, where the independent variable variation is at X axis, and the dependent variable variation is at Y axis. The role of the regression model is to find out the relationship between X & Y variables. Straight line equation for both variables

$$Y = a + bX$$

Where, intercept is ‘a’ and slope is b. If both these are determined, then this will find out the straight line.

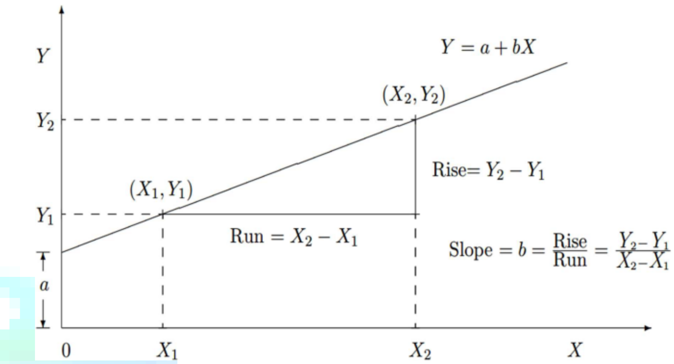

Fig. 2: Diagrammatic Representation of a Straight Line

Figure 4.1 shows the representation of a straight line, for the slope and the intercept. The straight line shown in the figure has the equation Y = a+bX. Intercept will be done where the line cuts the Y axis. This occurs when X will be zero, than only Y will be equals to ‘a’ and ‘a’ is the intercept for the line. Also, the ‘b’ is the slope of the line, which shows the flatness of the line. If we take, two points on the straight line as (X1, Y1) and (X2, Y2). The vertical distance between these two points are Rise (Y2 – Y1) and the horizontal distance between these two points are Run (X2 – X1) and the ratio of these two is the slope.

V. PROBLEM FORMULATION

Numerical analysis of Wire bending mechanism is the second objective of this work. We will use commercial software ANSYS 2020 R1 for the finite element analyses of the Wire bending mechanism geometry. In this section, we present the methodology and results of the static analysis of the Wire bending mechanism revolution under load. We see the equivalent stress, equivalent elastic strain, total deformation, directional deformation and Reaction Force for the Wire bending mechanism. While the existing finite element analysis software solves classic problems in a robust way, we want to be able to study the future forecasting of the performance on the basis of current results. In order to see these phenomena in a Wire bending mechanism, we need first to develop a Regression Model for Wire bending mechanism in MINITAB 19 software. Therefore, the third objective is to generate a Regression model on the basis of input and output results of the ANSYS 2020 R1 software. The basic steps adopted in the Regression are as follows: simulation and collection of data; analysis and pre-processing of data; design of the Regression model and testing of the Regression model; simulation and prediction with the Regression model; analysis and post-processing of predicted result. Regression technique was used to predict the performance of the Wire bending mechanism.

VI. CONCLUSION AND FUTURE SCOPE

In In this study, Wire Bending Mechanism has been analysed by Finite Element Method. A simplified and idealized finite element model by using symmetry assumption and a non simplified finite element model of process have been used in the analyses.

1. Wire Bending Mechanism has been examined.
2. The Equivalent Stress, Equivalent Elastic Strain, Total Deformation, Pressure, Reaction Force and Directional Deformation exerted by the Wire Bending Mechanism during a one complete revolution have been identified.
3. The aim of study is to predict the effects of performance parameters on the Wire Bending Mechanism during one complete revolution.
4. Following are the conclusions of Regression Analysis:
5. An empirical model has been developed by using Regression Model to determine the Total Deformation of Wire.
6. Good validation of results is obtained between computational results and predicted results.
7. Regression Model prediction would have been more accurate if the computational results were more.
8. This study indicates the ability of the regression tool as a brilliant technique in order to predict values of parameter with varying input variables also shows the dependency of predicted parameters over the other parameters.
9. The model implemented satisfactorily in the prediction of Total Deformation of Wire Bending Mechanism with different variables and the predicted values of the Total
10. Deformation with respect to the Equivalent Stress & Equivalent Elastic Strain is closely encountered with the FEM Total Deformation values.
11. The prediction made using proposed model shows a high degree of accuracy for Total Deformation of Wire Bending Mechanism obtained through model.

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