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Modeling and Testing the Spring Elasticity Properties with Variable User Defined Input Parameters Using MATLAB

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Abstract: ***Spring elasticity is dependent upon 3 basic components of spring Spring constant, Damping constant and mass of the object. In this project we will build a computer simulation model to see the effects of these 3 parameters on spring elasticity and its functionalities. We will use matlab and simulink to model spring elasticity equations. We will also modify the equations to enable user defined inputs of above 3 parameters. A simulink model is obtained using which we run computer simulation number times according to user defined inputs and model the response of spring elasticity with varying user defined input parameters.***

Keywords: Matlab, Simulation Technology**,** Simulink, Modeling, springs.

1. Introduction

A spring is defined as an elastic body, whose function is to distort when loaded and to recover to its original shape when the load is removed. The various important applications of springs are as follows: (Adetunji, 2012)

a) To cushion, absorb or control energy due to either shock or vibration as in car springs, railway buffers, air-craft landing gears, shock absorbers and vibration dampers.
b) To apply forces as in brakes, clutches and spring loaded valves.
c) To control motion by maintaining contact between two elements as in cams and followers.
d) To measure forces as in spring balances and engine indicators.
e) To store energy as in watches.

There are various types of springs theses are: coil springs, leaf springs, torsion bars and air springs (Adetunji, 2012)

1) **Coil springs:** is a mechanical device which is typically used to store energy and subsequently release it to absorb shock, or to maintain a force between contacting surfaces.
2) **Leaf springs:** are suspension springs made up of several thin, curved, hardened-steel or composite-material plates attached at the ends to the vehicle under-body.
3) **Torsion bars:** are a long straight steel bar fastened to the chassis at one end and to a suspension part at the other which when twisted provides the spring force.
4) **Air springs:** is a mechanical device using confined air to absorb the shock of motion. (Adetunji, 2012)

The shape change of the deformed component after unloading is called the elastic recovery. This behavior is been named as the spring-back in sheet metal stamping. The spring-back is defined in different words by many researchers. The geometrical change in the part after forming when the force from the forming tools was removed is denotes as spring-back. This behavior is most common in sheet metal formed components in which the one or two dimensions are much larger than the other ones. The dimensional inaccuracy in the stamped part is due to the spring-back. Some studies shows that the final shape of the parts depends on the amount of elastic energy stored in the part during the sheet metal forming process . The amount of elastic energy stored is a function of many parameters thus spring-back prediction is a complicated task. The shape error due to the spring-back considers as the manufacturing defect in sheet metal forming process. Another definition of the spring-back is referred to as the undesirable change of part shape that occurs upon removal of constraints after forming. It can be considered a dimensional change which happens during unloading, due to the occurrence of primarily elastic recovery of the part. Spring-back depends on the amount of draw-in during deformation. More the draw-in, more dominant will be the spring-back. Other process parameters which tend to give more spring-back were larger corner radius of the die set and lower clamping force. It has also investigated that the spring-back also depends on the material and process parameters. The influencing parameters for the strong spring-back were in descending order: punch corner radius, die corner radius, blank holding force, sup- porting force and lubrication. The study of spring- back behavior on ultra high strength steel sheet in bending was performed under controlled condition using CNC servo press. The spring-back amount measured for the steel sheets was almost proportional to the ratio of tensile strength to the elastic modulus. The spring-back was little sensitive to the forming speed and the holding time at the end of the process. Spring-back is a common occurrence due to bending of the sheet during forming whereas curl was observed in the sheet due to material sliding over the die radius. Curl is also the closest influential factor for spring-back. The non-linear relation predicted between curl height and the back tension. This understanding and prediction would not be clear without the investigation of hardening models. (Sarafian, 2013).Some of the numerical studies tried to predict the spring-back behavior for experimental comparison and several work-hardening models were evaluated in order to determine their influence on the numerical prediction of the spring-back phenomenon. Based on the set of experimental results the constitutive parameters identification was performed. Generally the spring-back results showed the sensitivity on the work hardening models. Due to the high level of equivalent plastic strain achieved in the U-shape channel the differences in the amount of spring-back prediction was not higher. However the differences found in the study where the strain level was quite low compared to the previous mentioned literature. The study performed on the work hardening models the differences exist with experimental comparison and were associated with the predicted through thickness stress levels. (Chetan, 2012) The accurate pre-diction of the spring-back through the numerical methods depends on the materials hardening rule. The constitutive equation for stress-strain curve for non-linear combined hardening rule was proposed depend on the non-linear kinematic hardening theory of Lemaitre and Chaboche and Barlat89's yielding function. It was found that the isotropic hardening rule over predicts the spring- back behavior compared to the proposed model. It was also observed that Barlat89's and Hill48's yielding function gave the better co-relation with experiments than the von-Mises yielding function . This tells that the spring-back was sensitive to the work-hardening model. In the forming of U-shape channel it was identified that the strain path changes and was associated with the bending-unbending of the channel during forming. It was also noted that the strain achieved in each strain path are equally important as the strain path changes during the forming . It was also shown that one model predicted larger spring-back angles for some materials and smaller for other ones according to the predominant strain-paths and strain-path changes. The comparison on the influence of the work-hardening models on spring-back, different trends was expected depending on the selected sheet metal formed part as well as the process conditions. (Chetan, 2012)The numerical prediction of the spring-back was strongly dependent on definition of the constitutive model for the sheet metal mechanical behavior under the change in strain-path and the occurrence of the stress reversal during the bending to unbending transition on the die radius . In addition the investigation on number of integration points through thickness has done by many researchers to understand the accuracy in prediction . They recommended the implementation of 25 to 51 IP for 1% accuracy in the prediction. Previous studies performed on the influence of change in elasticity during plastic deformation noted quite interesting outcomes found that some simulation results was in low precision when compared to the experiments. It was found that the E-value varies after plastic deformation. Thus consideration of this change in E-value would be needed to improve the spring-back simulation. The decrease in E-value was experimentally shown and proposed the linear relation between E-value and the plastic strain. The analytical model developed with the consideration of change in E-value for the estimation of top roller position predicted larger spring-back compare to with the constant E-value. (Chetan, 2012) Literature articles and text books are flooded with sections describing the characteristics of linear oscillators . One quick review of these resources reveals these are confined limited to mechanical systems. In the area of electro and magneto-dynamics, the author thoroughly has investigated scenarios of nonlinear oscillators . (Sarafian, 2013)Laboratory setups conducive to these scenarios have been proposed, and for the magneto-dynamic case the validity of the theoretical model is qualified with actual data. For the sake of completeness, therefore, it is essential to fill in the gap considering a practical scenario conducive to a nonlinear mechanical oscillator. Although the latter is the main motivation of tackling the issue, however, in the course of analyzing the problem we stumbled on a mathematical observation constituting our secondary objective. (Sarafian, 2013)

2. Literature Survey

Problems by simulating theoretical models is part of new technology that has taken place alongside pure theory and experiment during the last few decades. Numerical simulations permit one to solve problems that may be inaccessible to direct experimental study or too complex for theoretical analysis. Computer simulations can bridge the gap between analysis and experiment. Numerical simulations analysis and experiment cover mutual weakness of both experiment and theory (Sarafian, 2010). These simulations will remain a third dimension in ultrasonic measurements, of equal status and importance to experiment and analysis. It has taken a permanent place in all aspects of ultra-sonic measurements from basic research to engineering design. The computer experiment is a new and potentially powerful tool. By combining conventional theory, experiment and computer simulation, one can discover new and unsolved aspects of natural process. These aspects could often neither have been understood nor reveled by analysis or experiments alone. There might be many use of ultrasound but a common one is its application to non-destructive evaluation. Pulsed ultrasonic is finding an increasing number of applications in research and industrial nondestructive testing. In such evaluation, one tries to obtain information about the inner parts of an ensemble without dismantling it. In an ultrasonic system, a transducer consists of a collection of material layers. The design and optimization of a multi- layered transducer is a complicated engineering task that involves knowledge of physical acoustics, analog electronics, and the acoustical properties of the materials involved. This task is made even more difficult by the lack of available information

about frequency and thermal dependencies of these materials characteristics. The optimal combination of suitable materials can be found by trial and error, but not without considerable time and cost, both of which can be minimized through the use of simulations. The aim of this paper is to present a tool which provides a simulation of the received signal prior to construction. Of the different ways to model the electro-acoustic system, a total electrical simulation tool is used for the following reasons. First, the modeling of acoustic wave propagation in one dimension by electrical lines can be handled with a certain ease; second the associated electronics used to excite, receive, amplify and process the signals can be designed to meet the application's specifications prior to building system. This paper presents a simulation solution to ease the selection process. The electronic software simulation package used is PSPICE(Sarafian, 2010) . The use of PSPICE provides an opportunity to simulate the complex set of excitation electronics, the ultrasonic transducer, the material under investigation, and the receiving electronics. Electrical analogies of one- dimensional acoustic phenomenon have studied over the years. Mason (1942) , modeled electromechanical transducers with a lumped equivalent circuit. (Sarafian, 2010) Redwood (1961) , incorporated a transmission line into Ma- son's model to obtain useful information about the transient response of a piezoelectric transducer. With the transmission line, one can represent the time delay necessary for a mechanical signal to travel from one side of the transducer to the other. In the case of a plate transducer, the derivation of both models includes a negative capacitor. Using SPICE and an equivalent circuit approximating the negative capacitor, Morris and Hutchens (1986) [17], simulated Redwood's implementation of Mason's model. Krimholtz et al. (1970) [16], presented another equivalent circuit for elementary piezoelectric transducer. Leach (1994) [22], used controlled current and voltage sources instead of transformers. Leach mathematically derives his model by adding terms equal to zero in one of the devices electromechanical equations to obtain the form of the telegraphist's equation. Puttmer et al. (1996) [3], used a lossy transmission line in Leach's model to account for acoustical attenuation. Benny et al. (2000) [4], outlines a method that has been implemented to predict and measure the acoustic radiation generated by ultrasonic transducers operating into air in continuous wave mode. A comparison of experimental and simulated results for piezoelectric composite, piezoelectric polymer, and electrostatic transducers is then presented to demonstrate some quite different airborne ultrasonic beam-profile characteristics. San Emeterio et al. (2004) [19], present an approximate frequency domain electro-acoustic model for pulsed piezoelectric ultrasonic transmitters which by, integrating partial models of the different stages, allows the computation of the emission transfer function and output force temporal waveform. Hirsekon et al. (2004) , perform numerical simulations of acoustic wave propagation through sonic crystals consisting of local resonators using the local interaction simulation approach (LISA). The current work applies the approach of Puttmer et al. to liquids and piezoelectric transducer to obtain an electrical analogue of one-dimensional, acoustic wave propagation through such materials. In order to keep things at a manageable level, the following simplifications and assumptions are made. The acoustic propagation travels along one direction and consist of planner longitudinal waves, which are normal to the direction of propagation. (Sarafian, 2010).

3. Modeling

The piezoelectric phenomenon is modeled using con-trolled voltage and current sources . The equivalent circuit consists of the static capacitance C0 (capacitance between the electrodes), a transmission line (representing the mechanical part of the piezoelectric transducer) and two controlled sources for coupling between the electrical and mechanical part of the circuit. Suppose a ultrasonic pulse travels through a medium with a finite speed c (m/s). This pulse can be pictured as a disturbance to which the medium reacts to. In the case of longitudinal wave, the disturbance is a compression or rarefaction of matter, which the medium displaces to return to its equilibrium state. Spring-mass system is a classic physics problem(Chetan, 2012) . In this analysis the spring is idealized; it is assumed the spring is mass-less and linear. The first assumption is "justified" when the mass of the object outweighs the spring. The linearity for a coiled-shaped spring for most of the time is enforced by not stretching the spring be-yond its plastic limit. Under these assumptions the equation describing the motion of the object is a second order linear differential equation; it is trivially solved with analytic sinusoidal solutions. This scenario is modified slightly when a nonlinear mass-less spring is considered The latter reference also contains a wealth of bibliographic listed related articles. Recently, an electronic website posted an animated description of the Duffing related issues. However, neither these references nor the author's thorough literature search could identify a source describing the oscillations of an ideal perfect mass-less mechanical vibrator. The article that "best" aligns with one such mechanical oscillation is a suggested experiment given in . The authors of the latter reference have claimed their proposed experiment would produce data that is compatible with the description of the Duffing equation. However, a careful analysis of their setup and suggested analysis reveals the mass of the elastic metal strip is ignored. This leads to expect disconnect between the data and the proposed theory. (Chetan, 2012)

Motivated with identifying the missing practical design of mechanical oscillations of an ideal/perfect mass-less oscillator, the author designed a spring made of a static electric field, and called it an electric-spring. The point is a spring made of an electric field is a mass-less spring. In other words, there is no need to make assumptions justifying the smallness of the spring's mass. This makes the spring ideal. Furthermore, knowing the fact that the strength and the orientation of a static electric field is a function of the distribution of the static electric charge makes the number of the designs limitless. For the sake of transparency and simplicity, in this article we consider a circular charged ring with a uniform positive charge distribution. The field along the axis through the center of the ring and perpendicular to the plane of the ring sustains its direction; it orients itself along the symmetry axis heading outward from the center. The strength of the field however, varies as a function of distance from the center; interestingly, its variation is not linear. Placing a negatively charged particle along a horizontal frictionless axis of the ring exerts a force on the particle accelerating it toward the center of the ring. (Chetan, 2012).

4. Scope and Methodology Used in the Paper

1. We derive the traditional spring elasticity equations given by mass of the object (m), spring constant(k) and damping constant(b).
2. Transform above equation in the form which can be modeled in matlab simulink model.
3. Building a simulink model according to tradition spring elasticity equations.

4. Now embedding the parameters b, k and m in such a way that they will be defined by user each time an output is needed.
5. Providing the values to b, k and m to moderate limits
6. Simulating the system and running the system simulation for t = 10 units.
7. A zig zag curve is obtained when mass of the object is low showing spring is working within its elastic limits.
8. Increase mass of the object massively to 1000 units with same values of b and k.
9. Running the simulation for t = 10 units
10. A straight line curve is obtained.
11. Straight line shows mass is beyond the elastic limits and spring breaks down.
12. Simulation shows Elasticity behavior of a spring varies with varying input parameters by the user.

5. Results and Conclusion

We have build a system to measure spring elasticity using matlab and simulink functions as shown in figure 1

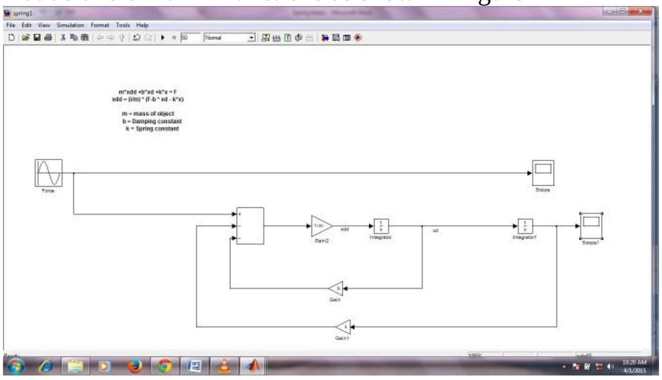

Figure 1

In the model we have given equations to measure elasticity of a spring
Here
M = mass of the object
B = damping constant
K= spring constant
Initially we will run the system 50 times with values of b, k, m defined by user.
Initially we will keep the value of m that is mass of the object to moderate limits, and give the input values as shown in figure 2

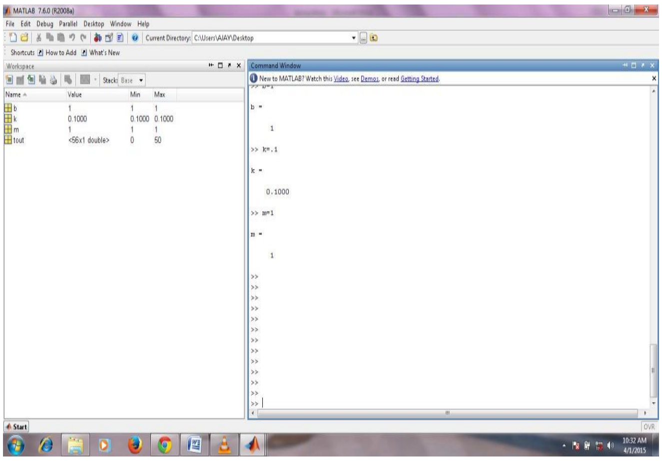

Figure 2

Here
b =1 units
k =.1 units
m =1 units
It gives the curve shown in figure 3,

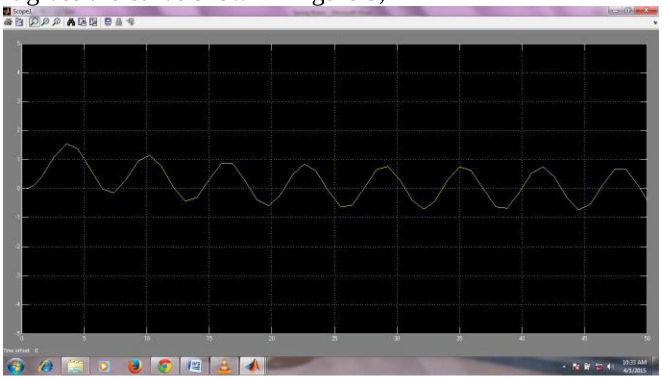

Figure 3

it is a zig zag curve which shows that elasticity of a spring is upto tolerable limits when mass of the object is kept under check Now if we increase the mass of the object to high units , keeping damping constant and spring constant to smaller units. We see elasticity of spring breaks down and it can not tolerate increasing mass and reaches beyond its elasticity limits. This is shown in figure 4 and 5

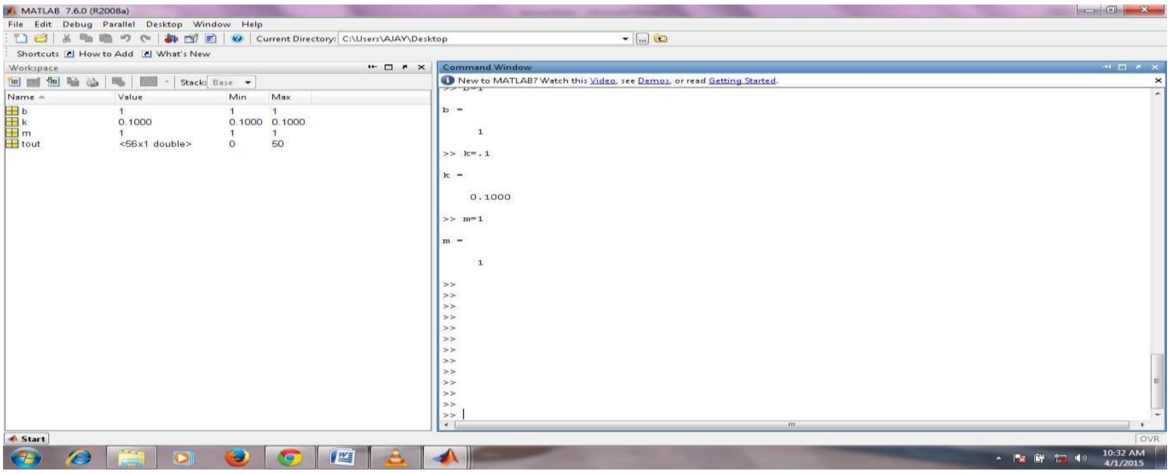

Figure 4

Figure 5

Here
b =1 units
k =1 units
m =1000 units
From figure 5 it is evident that spring breaks down as mass reaches beyond its elasticity limit.

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