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Material Types and Wall Thickness Effects on Bourdon Tube Tip Travel using Solid works

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Abstract: ***Bourdon-type pressure devices are used to detect pressure in industrial installations and pressure monitoring systems. Bourdon tubes are manufactured in various engineering shapes like circular-C, helix, and spiral, to serve the use of this tube in terms of positioning and accuracy. The tip of the Bordoun tube is a pressure-sensitive element. The applied input pressure causes the tube tip to be shifted or translated from the initial position. In this study, the pressure measurement in Bordoun tube was simulated at different sections and different axial ratios of multiple metals to obtain the best tube tilp deviation using the Solidworks program. Simulation results expressing the differentiation of tip travel values using four materials, three axial ratios, and four cross-section types. The results show that best material in terms of maximum tip travel was Zinc AZ-12, and for any material and regular wall thickness, the axial ratio (0.3) gives the best response. Also, the results show other materials' response and effect of change axial ratio.***

Keywords: Borden tube - pressure gauge - axial proportions – tube tip travel - Solidworks.

I. INTRODUCTION

Bourdon tube, a popular mechanical pressure measurement guage, although of modern technologies in this field, it still used because of its simplicity. Bourdon tube fabricated from rough alloy of mixture of alloys, and this alloys must minemum value of elasticisty to ensure the move of the tube when messure small pressure values. It was important to make a mathematical study of material elasticity effect on bourdon tube tip travel and what had been achieved with (Conway 1995).

The Idea of using the elasticity of material to indicate the pressure value was invented by the French engineer Eugène Bourdon who used this functionality in an elastic C-shaped tube with an oval cross-section. When applying pressure inside the tube wall, the will cause an expansion towards the center of the C-circle because of the free end of the tube. This displacement of tube tip (the end of the bourdon tube) could be in one or two millimeters, so its hard to be recognized by a human, so it was necessary to insert a mechanism to convert this small translate into clear rotation movement. After this invention, a lot of trials of enhancing the sensitivity of bourdon tube were made by three orientations: wall thickness value (axial ratio), Cross-sectional type and the used materials. The commonly used materials are phosphor-bronze, silicon-bronze, beryllium-copper, Inconel, and other C-Cr-Ni-Mo alloys, and any material can show good flexibility. Bourdon tube also has some error tolence but this problem could reduce by the thermal processing [2].

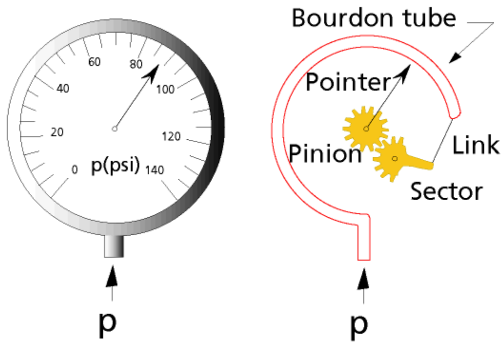

Fig. 1. Pressure gauge and Bourdon tube with pointer mechanism [3]

II. LITERATURE REVIEW

A few published research discussed the material properties of the bourdon tube and their effect on the sensitivity of pressure measurement. (Kardos 1957) has deal with the deflection of the bourdon tube and its variation according to many materials, and he attached a lot of plots and tables that illustrate the tip travel sensitivity according to those materials [4]. (Bansil and Abdullah 1985) use finite element modeling to characterize the bourdon tube attitude with many materials and results show that the stress of the tube can be decreased by merge the groove edges [5]. (Conway 1995) discuss the mathematical model of the bourdon tube and try to characterize the relation between the tip travel and mechanical and physical properties of used material in the bourdon tube [1].

III. METHODOLOGY

The aim of this research is using Solidworks to simulate the C-type of bourdon tube with specific materials and special dimensional parameters of bourdon and discuss the main differences between the results.

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A. Design bourdon tube

The first prototype of bourdon has been designed using Solidworks Fig. 2 by basic

geometrical tools [6] according to table 1. And with this parameters:

Section Dimension	a=7.33mm	b=3mm	h=1.521mm
Tube Dimension	R=63.09mm	μ=130°	

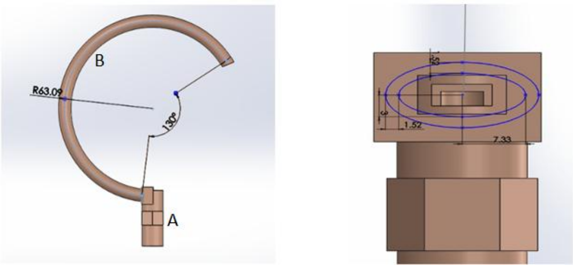


Fig. 2 Solidworks model of Bourdon tube

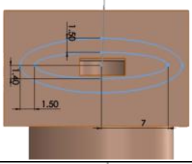
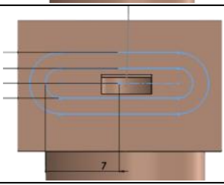
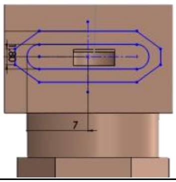
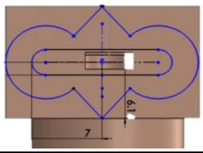
Table 1 using tools and feature for create bourdon tube in solid works

	A (Fig. 2)	B (Fig. 2)
Sketch tools	• 2D sketch • Boss Extrude • Extrude Cut	• 2D sketch of cross-section • The path of C shape • Sweep using the path

As what mentioned before, bourdon has a lot of cross-sectional shapes and each shape has a specific parameters affect on its sensitivity and movement. In our research we will work with C-type only.

This study will use four types of wall thickness shapes (cross-section) and three value of axis ratio (between major axis (a), and minor axis (b)) for each cross-section, and table 2 illustrate their parameters. The three values of axial ratio will be: b/a = {0.2 , 0.3 , 0.4}.

Table 2 –2d sketch according to wall thickness shape

Cross-section shape	2D Sketch
Regular thickness - Oval	
Regular thickness - Rectangle	
Irregular thickness - 1	
Irregular thickness - 2	

B. Bourdon tube Materials

The material of bourdon plays a big rule in sensitivity, stabilization of tip travel and the range of measured values. In the industry field, the companies try to make a survey about the most appropriate and efficient material for bourdon tube sensitivity either normal material or composite.

In this research, we simulate bourdon tube behavior using 4 material types: Nickle span, Bronze, Zinc and Brillyiom copper, and the table below shows the physical properties of them. According to http://www.matweb.com/ website, we collect the mechanical properties of these materials:

Table 3 Materials mechanical properties

		NI-SPAN-Alloy 902	Phosphor bronze 5% Sn, UNS C51000	Zinc ZA-12 (Zn-11Al-1Cu-0.025Mg)	Beryllium Copper, UNS C17200
Elastic Modulus	kgf/cm^2	185000	110000	83000	127500
Poisson's Ratio	N/A	0.29	0.341	0.25	0.3
Shear Modulus	kgf/cm^2	65000	41000	253	50000
Mass Density	kg/cm^3	8050	8860	7140	8250
Tensile Strength	kgf/cm^2	1210	470	205	1380
Compressive Strength	kgf/cm^2	125	125	230	125
Yield Strength	kgf/cm^2	760	380	157	1050
Thermal Expansion Coefficient	/ºC	7.60E-05	2.75E-05	2.75E-05	7.60E-05
Thermal Conductivity	cal/(cm-sec-ºC)	12.1	84	116	12.1
Specific Heat	cal/(kg-ºC)	395	395	450	395

C. Solidworks simulation parameters

Solidworks has a wild range of libraries and tools of mechanical and dynamical simulation, but in our study, we used only the static study of bourdon tube which consist in Solidworks simulation of three main parameters [7]:

- Specified material: each time with use different one according to table 3.
- Applied pressure or forces: we apply a regular pressure inside the internal wall of bourdon tube Fig. 3 with variable value for 0 MPa to 1 MPa
- Fixed area: illustrated with green pins on Fig. 3 and refers to the fixed part of bourdon.

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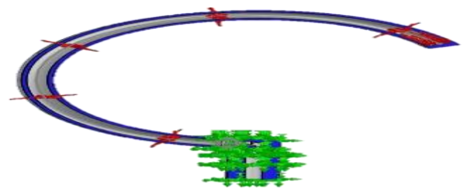


Fig. 3 Solidworks model of Bourdon tube with simulation components

IV. RESULTS AND DISCUSSION

According to 12 tubes (bourdon tubes with specific wall thickness and axis ratio) for each material, we have to make simulation of applying pressure for 48 moduls in Solidworks.

For easy comparison firsty we show the tip travel (Displacment) using Solidworks for Zinc material Fig. 4, then we illustrate the difference between the sensitivity of materials with three axial ratios Fig. 5.

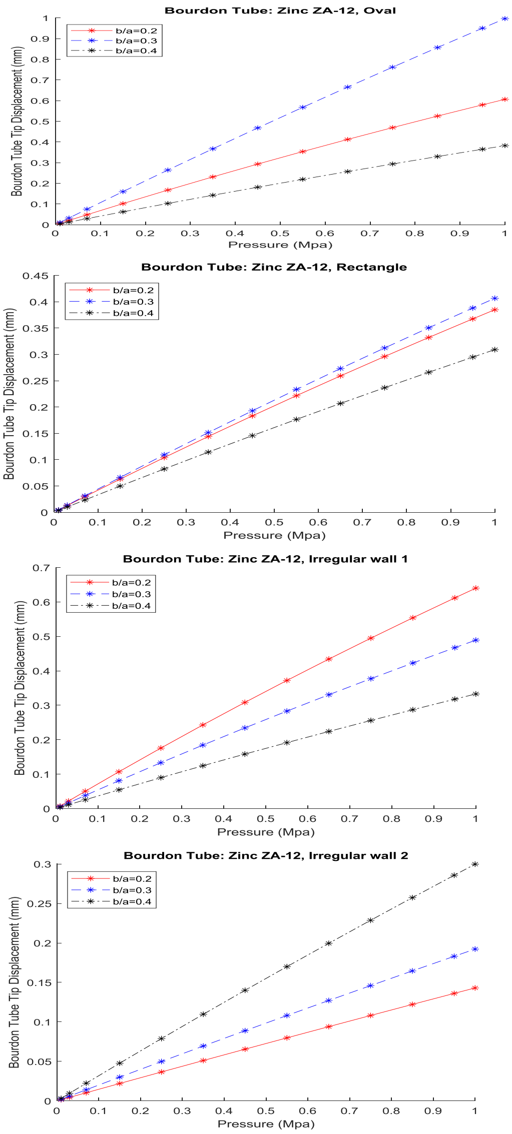


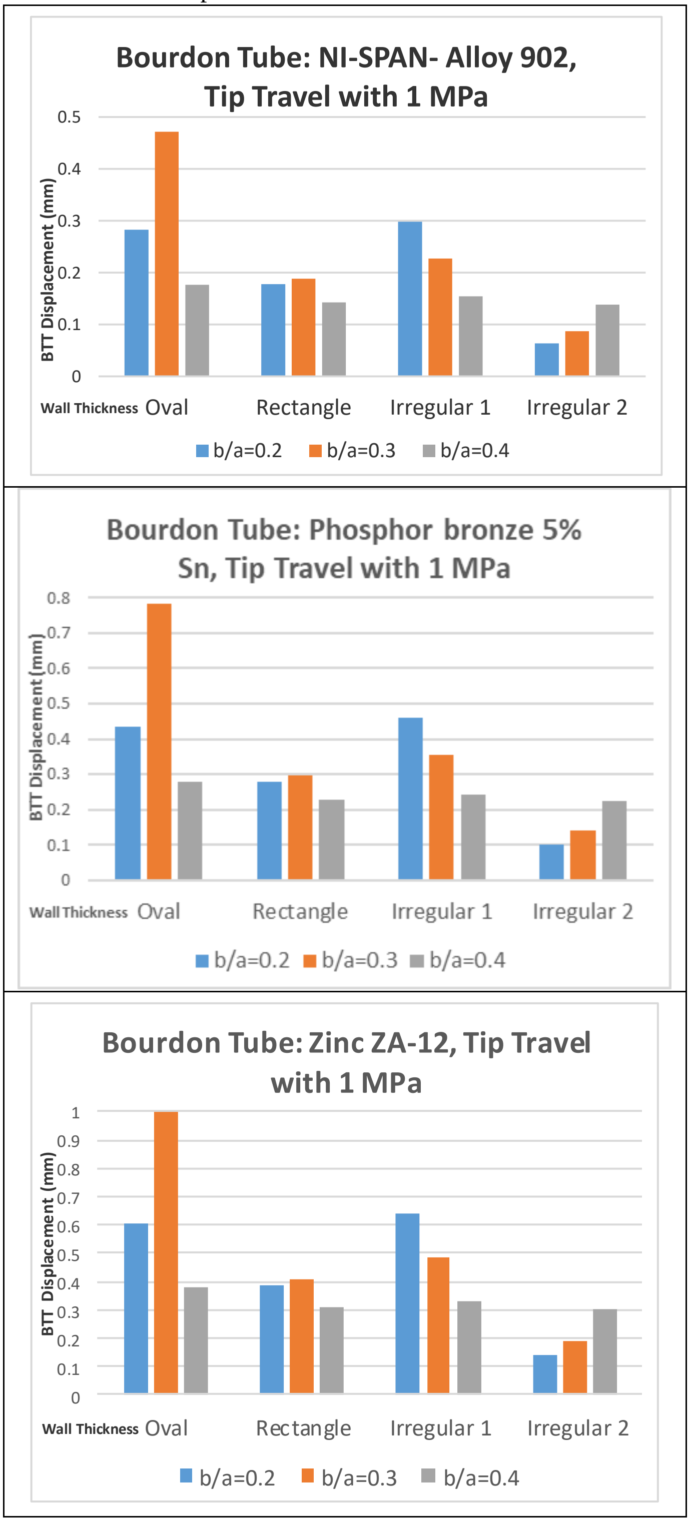
Fig. 4 Tip travel of bourdon tube from 0 ~ 1 MPa with Zinc material, the four cross-section types and three axial ratios using Solidworks simulation

The regular thickness with oval shape has the largest displacement with b/a=0.3, but the rectangle shape show the half response.

The irregular 1 wall thickness gives more sensitivity and large displacement at b/a={0.2, 0.3}, But the more complicated cross-section (irregular 2) give less displacement.

V. CONCLUSION

After making a rapid review of the bourdon tube and its specification, we introduced the general principle of the common ways of enhancing or edit the sensitivity of bourdon tip travel according to material types, axial ratio and cross-section shape.



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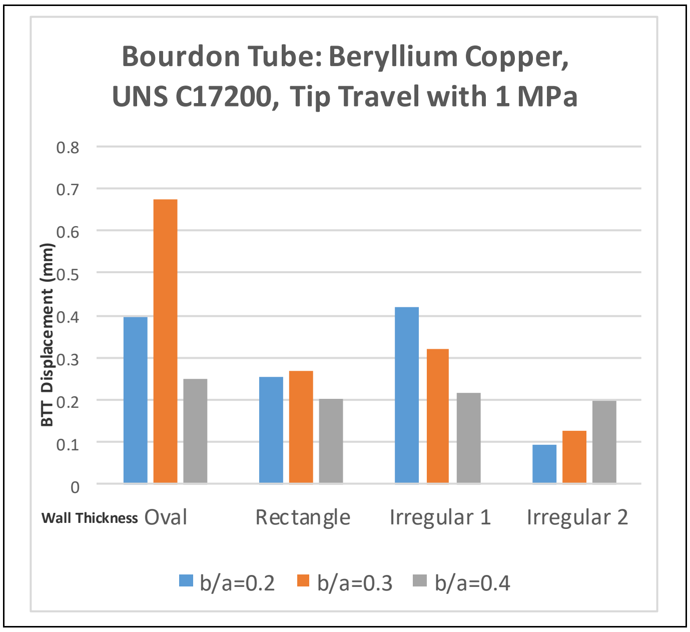

FIG. 5 TIP TRAVEL OF BOURDON TUBE FROM 0 ~ 1 MPA WITH FOUR MATERIALS AND THREE AXIAL RATIOS USING SOLIDWORKS SIMULATION

Simulation results of zinc bourdon tube Fig. 4 with three axial ratios show that in the regular thickness (Oval), the maximum tip travel happen when we use axial ratio b/a=0.3 and because of that, the oval shape is the most useful one in the commercial editions., but the other regular thickness shows less response. Irregular thickness (irregular 1) has also a good response after oval shape, but we can conclude that the irregular shape when getting more complicated will minimize its displacement.

For all material, the best magnitude of the displacement was with Oval cross-section and b/a=0.3, and between the materials, Zinc ZA-12 was the best one of maximum tip travel with approximately 1mm. About material differentiation, we see that Zinc has always the best displacement with b/a=0.3, and the irregular 1 cross-section has the second-best one with b/a=0.2, also the rest of the materials. Finally, we can say that for regular cross-section the best axial is b/a=0.3, but for irregular (similar to oval) is b/a=0.2.

ACKNOWLEDGMENT

This research belongs to the Ph.D. research of Feras Saleh which concerns the role of the properties of the materials in Bourdon tube sensitivity. We will try to convert this simulation into real values by fabricating similar bourdon tubes, which designed by Solidworks and compare the experimental values with the numerical.

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