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A Retrospective Study for Comprehensive Design of Force Transducers

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Abstract

Force measurement is very vital in different engineering applications and the force to be measured varies from few Newton to mega Newton. The force transducers are designed as on the basis of analytical method as well as on the basis of computational method. The design is being validated by experimental observations once the force transducer is fabricated. A rigorous validation of different methods adopted regarding the design of force transducers lead to the appropriate functioning of the force transducers. The present paper intends to describe a comprehensive procedure adopted to design the force transducers and states the procedure for rigorous verification of the procedure adopted.

Keywords: *Force transducer, axial deflection, stress, strain, applied force*

1. Introduction

The force transducers are very commonly used for force measurement and may be different types like dial gauged ring shaped force transducers to modern Hall Effect based force transducers. They may be strain gauged force transducer or tuning fork type force transducers. Each types of force transducers posses their specific characteristics, making them suitable for particular applications. Some force transducers are used only for low force related applications, while other might be suitable for only higher capacity force transducers. If a careful analysis is made, it is found that either dial gauged force transducer or strain gauged force transducer is widely used over the varying range, from few Newton to mega Newton, for different applications. Such capabilities makes these force transducers most reliable media for measurement of force over so many decades [1-4].

The force transducers consist of essentially a sensing element (mechanical) and a suitable measuring device (dial gauge or strain gauges with data acquisition system). The elastic sensing element undergoes deflection, when the external force is applied to the force transducer and the deflection (in case of dial gauged force transducer) or strain (in case of strain gauged force transducer) [5-6].

2. Design Studies of Force Transducers

The force transducers are studied for their sensing element. The sensing element may be symmetrical or asymmetrical. Most of the force transducers are of axis-symmetrical shape to take advantage of symmetry. This help in taking advantage of their symmetry, while designing the sensing element of the force transducer and minimizing the eccentricity of the axis of force application. The force transducers are available commercially with nominal capacity from few Newton to mega newton. Such force transducers are generally digital type and their precision and uncertainty of measurement vary in accordance to design / applications [7-8].

Ring shaped force transducers present the simplest form of the force transducers used over many decades. Such force transducers conveniently equipped with dial gauge as the deflection measuring instruments. Recent research reported digitization of conventional force transducers by applying strain gauges [9]. Ring shaped force transducers have been successfully modified to square ring and hexagonal ring shaped force transducers in addition to octagonal and extended octagonal ring shaped force transducers [10-11].

2.1 Scheme for Design Investig

The following steps are taken into account regarding the design procedure of force transducers:

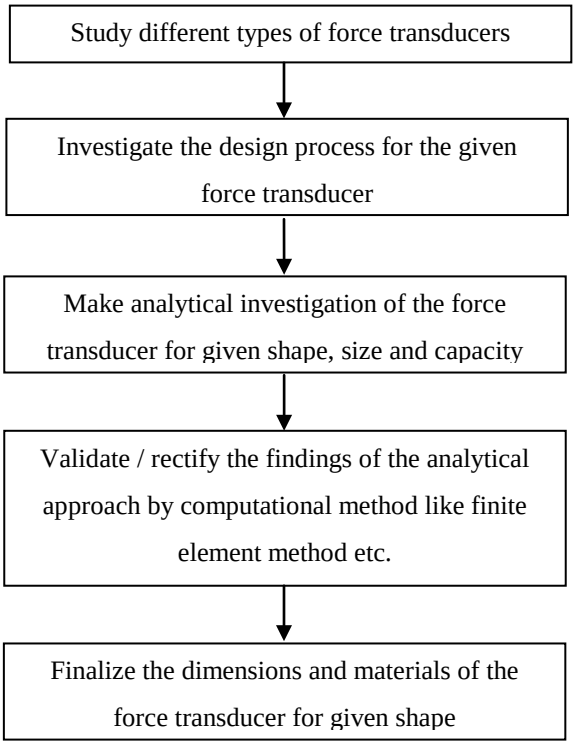

Fig. 1. A typical approach for design of force transducers

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2.2 Role of Analytical Studies

Analytical investigations serve as the base for any design related investigations and helps in analyzing the study with reference to conventional theories applicable. Sometimes, it helps in developing the modified or empirical expressions, if any. A force transducer is a typically curved bar or beam. Such elements could be easily evaluated by the conventional methodology. The sensing element undergoes deflection or deformation under the action of external force applied. The deflection and stress – strain pattern are easily evaluated by the conventional or analytical method. Such methodology helps in preliminary evaluation of design aspects of any force transducer like stress – strain, strength, deflection etc. Once, the finding of the analytical method is satisfactory enough, the other approaches are adopted later [12].

2.3 Role of Computational Studies

Computational studies are significant in critical evaluation of force transducer as a structure and as a sensing element. Computational studies are critical in validating the findings of the analytical methodology as well as defining the dimensions and other features of the force transducers. A number of cases are reported by the researchers earlier that significant deviation has been obtained in the findings of analytical observations to the computational findings [13].

2.4 Implications of Computational Studies

The stress – strain plots could be very helpful in locating the suitable places over the surface of force transducers, where strain gauges could be applied. For the given shape of the force transducer, stress – strain are minimum at a given location and maximum at the point of application of concentrated forces [13].

3. Fabrication of the Force Transducer

The sensing elastic element of the force transducers are machined as per the specified dimensions. The dimensions of the force transducers have been calculated according to the analytical method and finite element analysis has revealed that the stress – strain are in within safe limits. The material EN 24 steel has been selected due to its good elastic properties.. Once, the sensing element has been fabricated, it is subjected to heat treatment to get requisite hardness (HRC scale). The hardness value is generally 40-45 on HRC scale. After obtaining hardness of requisite range, the sensing element is finished and the surface roughness throughout the specimen is restricted to few microns. The sensing element could be electroplated for better aesthetic features also [14].

3.1 Application of Strain Gauges

The strain gauges have been applied on the suitable locations as identified on the basis of computational investigations. The machined element has been subjected to the force equal to nominal capacity, i.e. full capacity. The surface at the specified locations for application of strain gauges has been cleaned thoroughly and the surface roughness is restricted to few microns for proper application of strain gauges. Poor surface finish may lead to improper application of strain gauges and the metrological investigations may not be able to properly evaluate the force transducers. Proper cure has been taken before and after fixing the strain gauges. The strain gauges have been arranged in form of a Wheatstone bridge. The Wheatstone bridge is balanced if no external force is applied to the force transducer. When an external force is applied to the force transducer, the Wheatstone bridge gets unbalanced and the output of the Wheatstone bridge in form of an electrical signal is a measure of the force applied. It may also be well understood that the electrical output is proportional to the stress - strain, which in turn is proportional to the force applied. The electrical output may be displayed with the help of a suitable data acquisition system (or digital indicator) [17].

4. Conclusions

The paper discusses the intensively the procedure adopted for the design investigations of the force transducer. The paper discusses different design approaches. The paper discusses implications and significance of different design methodologies.

Fabrication procedure with application of strain gauges mentioned. Salient points regarding the application of strain gauges are mentioned.

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