Abstract

The Robotic hands are essential components of any Robotic system as they are required to work as human hand. Nowadays it is more and more important for robots to serve and help people, especially the old and the disabled. There are about 1,000,000 people who had an amputation of a hand or a complete arm worldwide. The main factors for a loss of upper or lower limbs are accidents followed by general diseases and injuries. The various multi-fingered or artificial hands that are available are essentially based on linkage-mechanisms such as wires, cables and chains, belts, artificial muscles, or hydraulic and pneumatic elements, etc. The multi-fingered hands actuated by pneumatic artificial muscle are costly and difficult to miniaturize. The need for an adaptable hand with flexibility, dexterousness and load carrying capacity analogous to the human hand seems to be the ideal one for robotic or prosthetic application. The artificial hands presently in use are complicated in design and control structure and also costly to be implemented for robotic or prosthetic applications.

There has been a lot of research on the flexible pneumatic rubber or polymer based actuators for soft gripper applications but not for the investigation on the multi-jointed multi-fingered prosthetic hand based on asymmetric bellow flexible pneumatic actuators. Several kinds of flexible pneumatic rubber actuators have been developed and reported with two or more internal chambers having symmetric cross section or attached to a joint to create bending motion. Even though the flexible micro actuator [FMA] with two or more chambers provide multiple degrees of freedom, it requires multiple pressure supplies, valves and sensors as well as complicated manufacturing. Compared with the typical FMAs, the flexible pneumatic actuator [FPA] uses spring or wire rather than fiber as its constraint, which results in the bending deformation of the actuator. Instead of two or three internal chambers in FMA made of rubber or fiber-reinforced rubber, the proposed actuator not only has a single internal chamber but also simple, compact, stable, less in weight and easy to manufacture.

In this research work, the focus is mainly on the design, analysis and manufacturing of asymmetric flexible pneumatic tube actuators (AFPA) and asymmetric bellow flexible pneumatic actuators (ABFPA) for the fabrication of light-weight, low cost multi-fingered hand with good adaptability and faster opening and closing response time of the fingers based on anti-Bourdon tube principle. To show the principle of actuator deflection and its application, a novel anti-Bourdon tube pressure gauge or transducer has been designed and constructed based on the anti-Bourdon tube principle. Various mathematical models have also been developed to

explain the bending of the various AFPA and ABFPA that have been designed, analysed, manufactured and tested. The mathematical models developed have been found to be in close agreement with the simulation results obtained with softwares such as Ansys and Abaqus and also experimental results. Models using the Euler-Bernoulli beam equation and Finite Element Modelling using one dimensional bending elements have also been studied. The results obtained from the simulation softwares have been fed in to Minitab software and linear equations for the deflections of the various actuators have also been obtained.

It is found that the effect of shape and eccentricity of the ABFPA plays an important role in the bending of the actuator and the deflection of ABFPA is influenced by the eccentricity up to a certain extent. The statics and dynamics can be predicted easily and the ABFPAs are designed efficiently. The dynamic modelling will offer an insight into the dynamic system, as it constitutes a fundamental step to understand how to design a soft robot. Various grippers such as three-fingered gripper with silicone rubber actuators, four fingered gripper with polymer and nitrile rubber actuators have been designed, manufactured and tested by lifting objects of various sizes, shapes and mass. Several actuator designs are compared and validated experimentally followed by the manufacture of various under-actuated multi fingered soft robotic hands for prosthetic application. A five degree of freedom (dof) multi fingered hand with square corrugated ABFPAs and a ten dof multi fingered hand with tapered triangular corrugated ABFPAs could lift objects up to 220 grams at five bar pressure. In the present work, two ABFPA are used in each finger to make a prototype thus achieving 2 dof finger as compared to 1 dof fingers generally provided in a soft hand. The total weight of the hand is about 950 grams. However, about 500 grams of weight can be reduced if both the battery and the mini compressor are removed from the arm of the hand and mounted separately. The total mass of the full prosthetic arm is just about half the mass of the conventional motorised prosthetic arm. It is possible to open and close the hand with a speed of 5 to 8 times faster than conventional prostheses. The entire hand including the arm can be built using materials worth less than US$ 800. Finally a five dof nickel-200 ABFPA multi-fingered hand has been designed and fabricated to increase the weight lifting capacity. This hand can lift objects with a maximum mass of about 450 grams at five bar pressure. This has shown that hands made of asymmetric metal bellow actuators can carry higher loads at five bar or higher pressures. In future with high pressure hydraulic pump, the metal bellow hand can lift objects of mass comparable with the commercial prosthetic hands.