Introduction Sensors are key components in an overwhelming wealth of systems for industrial and consumer applications. The new sensor device concepts will emerge to improve performance, e.g. sensitivity, and so on. Wearable instrumented garments, capable of recording body kinematic maps with no discomfort to the subject and showing negligible motion artifacts caused by sensor-body mechanical mismatch, are crucial in several fields of application. These sensors are “smart” because of their capacity to adapt to the specific mechanical properties of textile structures that are lightweight, highly flexible, stretchable, elastic, etc. Because of these properties, textile structures are continuously in movement and easily deformed, even under very low stresses. A normalized relative resistance is defined in order to characterize the electrical response of the sensor. Previous approaches to develop wearable monitoring systems have been made using traditional technologies such as accelerometers, gyroscopes, strain gauges [1], piezoelectric materials [2], fiber-optics [3] and pressure sensors [4], strapping the sensors to the body, adhering them to the skin, or integrating them into skin-tight garments [5, 6]. Conducting electro active polymers (CEPs), such as polypyrrole (PPy), polyaniline and polythiophene constitute a class of polymeric materials which are inherently able to conduct charge through their conjugated polymeric structure. PPy, in particular, has attracted much interest, as it is easily prepared in a number of forms, films, powders and composites and it has a relatively high conductivity and stability in its conducting state. When applied as a coating to soft flexible substrates, PPy has little effect on the mechanical properties of the substrate, but renders the entire structure electro active. Therefore, it is possible to make a conducting material that retains the desirable properties of a textile or other soft structure. PPy-coated textiles have been used in previous wearable sensing applications [7-10]. Integration of conducting polymer molecular template into textiles is similar to dyeing process and requires optimization of reaction conditions. The objective of this paper is studying the effect of quality and quantity of oxidant agent used in chemical deposition process on development of Polypyrrole coated fabrics as piezoresistive sensors. Experimental Materials Lycra/Polyester fabric provided by pooshineh baft Co, Iran. – Pyrrole monomer purchased from sigma-Aldrich, was distilled before use and stored in a freezer – Naphtalen disulfunic acid (NDSA), Ferric chloride, Sulfuric acid, Ammonium peroxodisulfate, Hydrochloric acid, Hydrogen peroxide, Silver nitrate, Ferric nitrate, Sodium nitrite, Trichloroacetic acid, Acetate vinyl, Copper nitrate. All of them were purchased from Merck and used without further purification – Deionized water. Sample preparation Lycra/Polyester fabrics were first pretreated in sulfuric acid (1M) for 30 minutes, at room temperature. All samples were then chemically polymerized in an aqueous solution containing 0.015M Pyrrole, 0.005M NDSA, and 0.04M of various oxidant agents at room temperatures for 2 hours. The effect of various oxidant agents in polymerization process have been investigated: (1) Ammonium peroxodisulfate, (2) Hydrochloric acid, (3) Hydrogen peroxide, (4) Silver nitrate, (5) Ferric nitrate, (6) Sodium nitrite, (7) Trichloroacetic acid, (8) Ferric chloride,

(9) Acetate vinyl, (10) Copper nitrate. Polypyrrole deposited on the fabrics surface. Then the black conductive fabrics were washed with deionized water and dried in desiccators, at room temperature (in order to avoid oxidative reaction in the air) Instrumentation Sensitivity assessment The strain stress properties of the Polypyrrole coated fabrics were obtained by using a smart motor (Instron tensile testing Instrument (DBBMTCL model)) equipped with a computer interface the data collection, under the standard testing conditions (T=25°C, RH=65%). The coated fabrics with dimensions 30mm*60mm were repeatedly stretched and relaxed at a controlled speed equal to 200 mm/min which corresponds to a strain rate of 5.55 %/sec (Fabric sensor length was 6cm) which is achieved in typical body movements and with the maximum extension up to 50% deformation in each cycles. The resistance change of the sensing fabrics in both stretched and relaxed states was recorded using a digital multimeter (ADm-552R model) to investigate their strain sensitivity. Results and discussion Sensitivity analysis The fabric strain gauge sensors are characterized with some of the sensor specification consists of, Sensitivity, Response time and Linearity. In order to adding up the extracted results from smart motor, the samples classified taking into similarity of elastic behaviour and then the best sample in each group in role of indicator was selected for final comparison. Sensitivity The sensitivity is defined as the input parameter change required producing a standardized output change. The fractional change in resistance divided by the fractional change in length is called the gauge factor (GF) and is an indication of the sensitivity of the strain sensor. Gauge factor is defined as the ratio of the fractional change in resistance to the fractional change in length: (1) where R0 is the resistance of non-stretched fabric and l0 is the length of non-stretched fabric sample. Relative electrical resistance versus time curves of Polypyrrole coated fabrics for some of the samples, are shown in Fig. 1 and the calculated gauge factors of these samples is illustrated in Fig. 2. (2) 3 4 Fig. 1 ‒ Relative electrical resistance versus time curves for samples prepared with the ratio of monomer to oxidant: (1) 0.75; (2) 0.375; (3) 0.187; (4) 0.15 Fig. 2 ‒ Typical gauge factor of samples given in Fig. 1 Sample 2 has the first grade in electrical conductivity and gauge factor synchronously. However, oxidant agent effect on polymerization reaction directly, but this reason is not enough to using oxidant agent in production process upper than an optimum value. In constant concentration of monomer, using oxidant agent upper than needed to polymerization of monomers, caused shortage of polymeric chains. This accident is equal to demolition of signal transition that decreases sensing ability of samples. Response time The response time can be defined as the time required for a sensor output to change from its previous state to a final settled value within a tolerance band of the correct new value.The calculated response time of sensing fabrics is presented in Fig. 3. Fig. 3 ‒ Typical response time of samples given in Fig. 1 Results show until now sample 2 in three important specifications such as electrical conductivity, gauge factor, and response time, are superior. In existing situation prepared sample with pH=5, can employed in a wide range of various

applications. Linearity Linearity is determined by the calibration curve. The static calibration curve plots the output amplitude versus the input amplitude under static conditions. Its degree of resemblance to a straight line describes the linearity. In fact linearity is the deviation between the curve of measured actual value and the regression curve. Relative electrical resistance versus strain % for some of the samples, are presented in Fig. 4 and the calculated Linearity percent of those samples is illustrated in Fig. 5. 2 3 4 Fig. 4 ‒ Relative electrical resistance versus strain % curves for samples prepared with the ratio of monomer to oxidant: (1) 0.75; (2) 0.375; (3) 0.187; (4) 0.15 According to the results in linearity percent, sample 2 turn over the first grade to sample 3. Samples 1, 4, taking into this factor (Linearity percent) over take from sample 2, too. Monotonous of coated nanoparticles network effect on linearity percent of sensing fabric samples. If coating process of conductive nanoparticles on fabric surface encounter to some obstacle will perform slow, that result produced film be unconfirmed to standard situation; but this accident can be received a positive distinction in processing of linearity percent, in this manner that decreasing of coating process velocity results decreasing of disturbance in process that will improve linearity percent of sensing fabric samples. Fig. 5 ‒ Typical linearity percent of samples given in Fig. 4 The effect of oxidant preparation conditions on sensitivity Fig. 6 shows Variations of relative electrical conductivity and strain % versus time for samples obtained using prepared oxidant with Ultrasonic homogenizer. Results show that, by comparison with previous samples, in constant polymerization conditions, this sample has a monotonous behavior needed for a desirable sensor. Fig. 6 ‒ Variations of relative electrical conductivity and strain% versus time for samples obtained using prepared oxidant with Ultrasonic homogenizer An important point about this produced sample is the repeatability of results. In fact results show that in this figure, are repeatable in successive cycles of special test or numerous tests in different times and this action is very important for a fabric strain gauge sensor. Gauge factor equal to 3.1, response time equal to 8s, and linearity percent equal to 97% are the specifications of prepared fabric sensor with this method. These results are according to electrical behavior illustrated in the article [11], and the monotonousness of macroscopic results can be related to morphology and evenness distribution of nanoparticles in fabric surface and structure. Conclusion The considerable value of linearity percent equal to 93% obtained for samples prepared with the ratio of monomer to oxidant equal to 0.187. According to results, preparation of oxidant agent is an effective factor on electrical conductivity and sensitivity. Production of a homogenous solution of oxidant agent with Ultrasonic stirrer improves products quality, clearly