iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: VIII Month of publication: August 2020

DOI: https://doi.org/10.22214/ijraset.2020.30878

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com

Spherical versus Capsule Shape Analysis for Wireless Endoscopy Applications

Fahad Mushabbab G. Alotaibi[1], K. Prahlad Rao[2], Naif D. Alotaibi[3]
[1, 2, 3]Department of Electrical and Computer Engineering, Faculty of Engineering, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract: In this paper, two different geometric shapes for wireless endoscopic applications are analyzed by simulating spherical and cylindrical objects inside the hollow GI tract (gastrointestinal tract). Currently, wireless capsule endoscope (WCE) is the most advanced technology used for visualization of the GI tract noninvasively. Wireless capsule endoscope employs a tiny camera that captures internal images of GI tract. The camera and associated circuitry is housed in a capsule shaped module. From our simulation experiments, we found that the spherical shaped endoscopic device has several advantages than the commercially used capsule shape for wireless endoscopic applications. Our results demonstrate that the velocity of sphere through the fluid is greater than that of the capsule shape through the same fluid. This means, the spherical shaped module excretes faster from the bowel and higher probability of easy exit from bowel after finishing examination. It is also found that the spherical has less pressure due to its geometry advantage than the capsule which has higher surface area and hence greater pressure in the laminar flow. From our findings, we suggest that the spherical shaped device is better substitute for the capsule shaped wireless endoscopic applications.

Keywords: Wireless endoscopy, sphere, capsule, gastrointestinal tract, COMSOL Multiphysics.

I. INTRODUCTION

An endoscopy is a procedure of seeing inside the body without surgical intervention. In the procedure, a flexible tube carrying a tiny light source and camera are moved inside the hollow organs such as gastrointestinal tract and the pictures from the camera are viewed on the display monitors. Currently, wireless capsule endoscope (WCE) is the most advanced technology used for visualization of the gastrointestinal (GI) tract noninvasively. Wireless capsule endoscope employs a tiny camera that captures internal images of GI tract. The camera and associated circuitry is housed in a capsule shaped module. As the capsule moves through the digestive tract of the human body, the camera captures thousands of pictures from inside and is transmits outside the body to a recorder which is held in a waist-belt on the patient. After complete the stipulated scanning, the capsule will come out of the patient through the stool. The wireless capsule endoscopy is also used in the diagnosis of lower GI (gastro-intestine) tract, small intestine and colon area. The typical length of the small intestine is 3-5 meter [1]. At this length it is difficult to use a wired/tube endoscope to screen all the small intestine and hence wireless capsule endoscope has been developed. The wireless endoscopy is relatively less risky than the conventional endoscopy [2]. It can also be used in colon area as an alternative to the colonoscopy, because it is safer and has lower risk. WCE has been used in early detection of colon cancer [3], small bowel tumors [4], detection of Occult primary neuro-endocrine tumors [5]; and for the diagnosis of inflammatory bowel disease IBD (Crohn's disease and ulcerative colitis). Besides these, other diseases that can also be detected are tissue abnormalities such as gastrointestinal bleeding, ulcer, erythema, polyps, and erosion [6]. In the upper GI, the use of the wireless capsule endoscopy in patients who have suspected esophageal disorders is possible and it is safe. Although large scale studies are required to confirm its utility in cirrhotic patients and GERD, researchers have come up with excellent results and opened a new era in esophageal examination [7]. The wireless capsule endoscopy has many applications in veterinary medicine also. It is being used in horses and dogs for diagnosis of intestinal distortion, obstruction, impaction, parasitic infection or adhesion [8]. Commercially, the customized product series for veterinary are available by their brand names in the form of sophisticated medicine.

The wireless capsule endoscope is made of CMOS camera, lens, battery source, silver polymers, LED (light emitting diode) flash and RF (radio frequency) transmitter. A matching receiver and a signal recorder are located external to the body. Many researchers have reported their findings on wireless capsule endoscope, focused on using computer for the recognition and detection of tumor and polyps in small bowel and colon images [9][10]. They have extensively focused on research relating to the power consumption in a bid to increase the battery life and the limitation of the battery in clinical use as the power is exhausted before the completion of tests [11]. The search further continued in using magnetic induction for real time localization, positioning and motion tracking of the wireless capsule [12].

At present, the shape of capsules used in wireless endoscopy is cylindrical in length and both ends are closed by hemispherical surfaces, resembling medication capsules. When they are swallowed by the patients for the diagnosis, the capsule module may get stuck in between the small intestine/GI tract endangering the situation for immediate removal by surgery. Therefore, our objective is to analyze the motion of the endoscopic module inside the cavity of organs, which are zigzag shaped in structure and; to propose an alternative geometrical shape to the capsule shaped module.

II. BRIEF HISTORY OF CAPSULE ENDOSCOPY

The first research in wireless capsule endoscope was reported in 1957 when radio frequency technology first became available. It was used to measure the temperature, pressure and PH values. As the technology of radio frequency and electronic component was lacking in precision and accuracy, it was not recommended for medical applications [13]. After the 50 years of its existence, i.e., in year 2000, an Israel scientist Gavriel developed the first generation of wireless capsule endoscope with CMOS camera and tested them in human successfully. In 2001, the FDA and CE human trial approved the first wireless endoscope capsule as trade mark M2A that meaning (Mouth-to-Anus), also developed the second model of M2A called the M2A Plus, got FDA and CE trademark approval - M2A PLUS, which was re-marketed as Pillcam. Since the first generation of WCE, more than 2 million capsules have been used by humans worldwide [14].

III. METHODOLOGY

Important parts of our digestive system are shown in the Fig.1. In the tube endoscopy, the imaging module is passed through the mouth; it traverses through the hollow organs under investigation to see any abnormality inside the specific organ. The series of hollow organs from mouth to anus is known as gastrointestinal tract (GI tract), including esophagus, stomach, small intestine and large intestine. In the WCE, the capsule module will enter the mouth and exits from anus. Since the GI tract has many twists, the capsule has to move through the twisted length of the tract. To study the motion mechanics during a twist, we simulated one turning phase between any two organs to simplify our computations. The results obtained for the single twisted path will be repeated at each turning length of the GI tract.

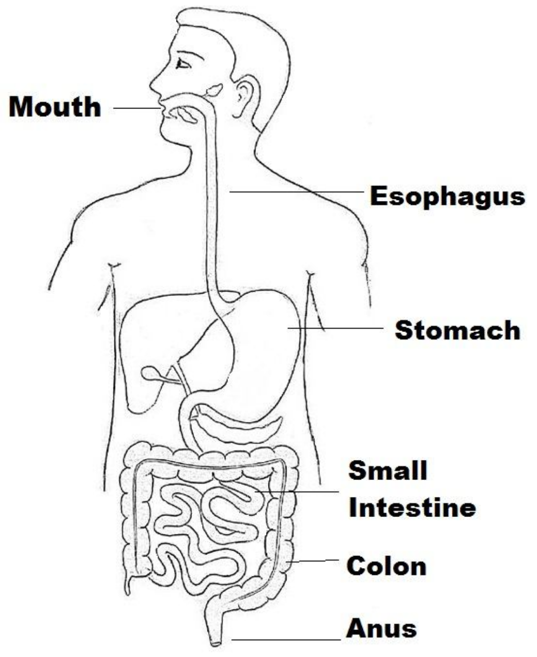


Fig.1: Schematic diagram of human digestive system.

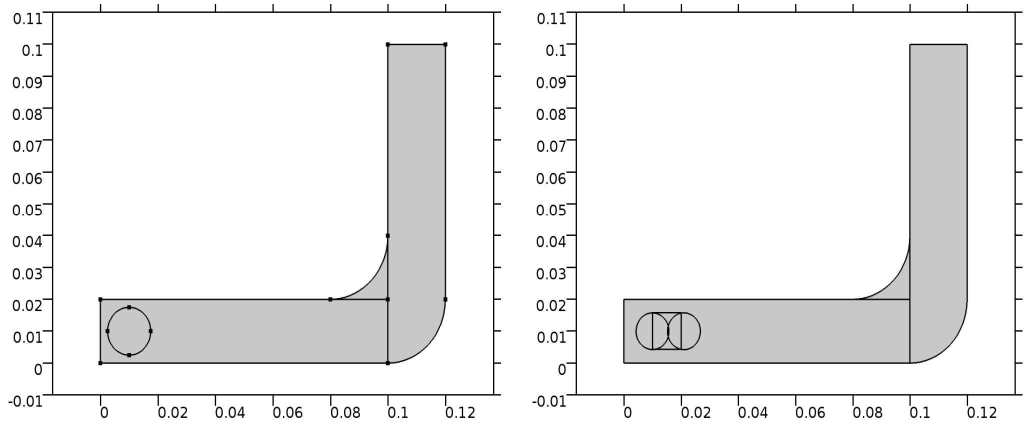
Flipped 'L' shape tubular structure was simulated in COMSOL Multiphysics software platform (COMSOL, Burlington, MA, USA). The simulated structure is considered as a crucial segment in the GI tract. Further, we simulated two different shapes which hold the light source and the circuit for capturing images during the motion. From the simulation, we studied the effects of existing capsule shape and the proposed spherical shaped objects moving across the segment. Then, we compared the sliding and rolling frictions of the capsule and spherical objects through the GI tract.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com

IV. RESULTS AND DISCUSSION

Two different shaped endoscopic modules and their motion in the GI tract were modeled and analyzed on COMSOL software platform. The Comsol Multiphysics is an engineering simulation software package that has an interactive environment which is more suitable for modeling and simulating complex designs and devices. The software enables to simulate physics based systems with engineering concepts. Any geometry can created or imported from outside domain to solve the required multi-physics ordinary/partial differential equations. The real solutions are based on the proven numerical method called FEM (finite element method). In the method, the model is discretized adaptively in the form of mesh and the solution of PDE for each discrete element is obtained.

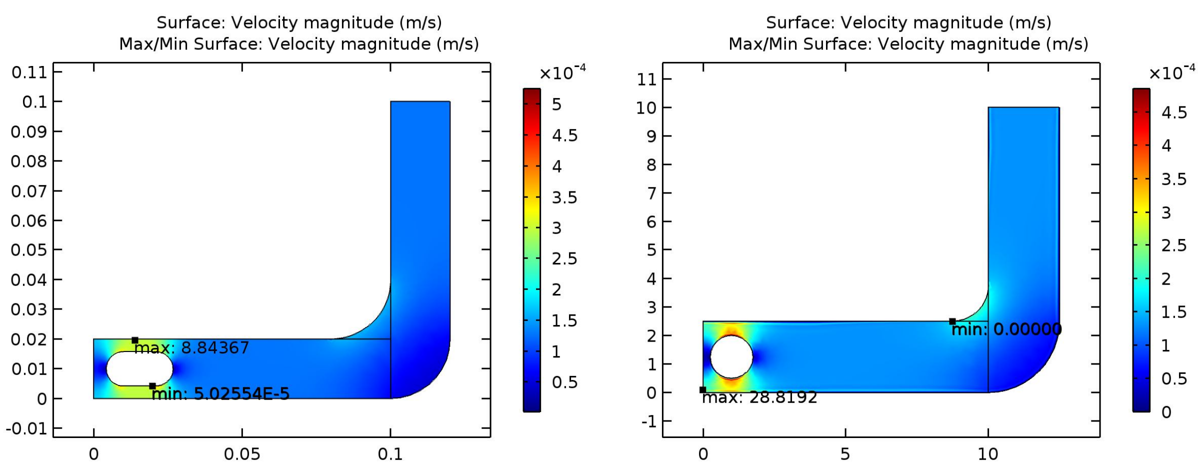
We have created a hollow tube filled with water, simulating the GI tract. The water is considered as the medium inside the tube because it is the major component of the fluid present in the tract. Then, a capsule and a spherical object are simulated in 2D separately passing through individual tubes. Fig.2 shows geometry of the model created in the software.



(A) (B)

Fig. 2: Simulation of segmental GI tract and the motion of endoscopic modules. (A) Spherical shaped (B) Capsule shaped modules.

Then, the models of capsule and spherical objects were solved. The solution was based on computational fluid dynamics (CFD) principles by considering laminar flow pattern of the fluid through the tube. Results (Fig. 3) show that the velocity of the sphere through the fluid is greater than that of the capsule shape through the same fluid. This means, the spherical shaped module excretes faster from the bowel and higher probability of easy exit from bowel after finishing examination. From engineering mechanics fundamentals [15], velocity and friction are inversely proportional each other. If the velocity increases, then the friction decreases. Increase in velocity with the spherical shaped geometry compared to capsule; friction on the lateral wall of the GI tract reduces. Moreover, the spherical shape has smaller outer surface area than the capsule. This enables the sphere smooth rolling in the fluid filled tract thereby reducing the rolling friction. It is to be noted that the rolling friction is less than the sliding friction while sliding friction is lower than static friction.

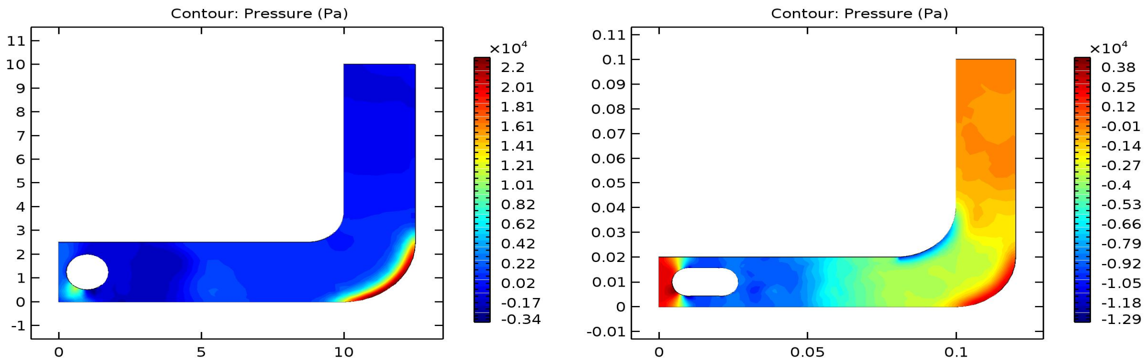


(A) (B)

Fig. 3: Comparison of velocity for spherical (A) and capsule (B) geometries in the GI tract.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com

Pressure exerting on both the shapes have also been analyzed. Fig. 4 shows pressure values on spherical and capsule geometries in the tube considered. From the simulation results, it is found that the spherical has less pressure due to its geometry advantage than the capsule which has higher surface area and hence greater pressure in the laminar flow and capsule shape has a more turbulent flow than the sphere shape.



(A) (B)

Fig. 4: Comparison of pressure for spherical (A) and capsule (B) geometries in the GI tract.

V. CONCLUSION

Computer simulation experiments were conducted by modeling GI tract to compare the motion of two geometries inside a fluid filled hollow tube. Spherical and capsule objects were simulated inside the tract in 2D. Assuming the hollow tube has water inside it and laminar flow pattern was considered. The GI tract has a series of components between the mouth and anus. The series of components comprises esophagus, stomach, small intestine and large intestine. Over the length of GI tract, several twists exits in between and we considered a single right angled turning point to simplify the computations. Modeling and simulations have been done by using COMSOL Multiphysics software. From the analysis, we found that the proposed spherical shaped endoscopic device has several advantages than the commercially used capsule shape for wireless endoscopic applications.

REFERENCES

[1] Turan, M., Shabbir, J., Araujo, H., Konukoglu, E. and Sitti, M. (2017). A deep learning based fusion of RGB camera information and magnetic localization information for endoscopic capsule robots. International Journal of Intelligent Robotics and Applications, 1(4), pp.442-450.

[2] Nawarathna, R., Oh, J., Muthukudage, J., Tavanapong, W., Wong, J., de Groen, P. and Tang, S. (2014). Abnormal image detection in endoscopy videos using a filter bank and local binary patterns. Neurocomputing, 144, pp.70-91.

[3] Shanmuga Sundaram, P. and Santhiyakumari, N. (2019). An Enhancement of Computer Aided Approach for Colon Cancer Detection in WCE Images Using ROI Based Color Histogram and SVM2. Journal of Medical Systems, 43(2).

[4] Lin, M. and Dung, L. (2011). A Subsample-Based Low-Power Image Compressor for Capsule Gastrointestinal Endoscopy. EURASIP Journal on Advances in Signal Processing, 2011(1).

[5] Fernandez-Urien, I. and Jimenez-Perez, F. (2014). Is string esophageal capsule endoscopy really better than esophageal capsule endoscopy in the right supine position for z-line examination?. European Journal of Gastroenterology & Hepatology, 26(6), p.685.

[6] Lanmeng Xu, Shanhui Fan, Yihong Fan, Lihua Li, "Automatic polyp recognition of small bowel in wireless capsule endoscopy images," Proc. SPIE 10579, Medical Imaging 2018: Imaging Informatics for Healthcare, Research, and Applications, 1057919 (6 March 2018);

[7] Jagadeesan, A & Jayaraman, Sivaraman. (2018). Formulation and statistical evaluation of an automated algorithm for locating small bowel tumours in wireless capsule endoscopy. Biocybernetics and Biomedical Engineering. 38. 10.1016/j.bbe.2018.07.003.

[8] B. Li and M. Q. -. Meng, "Tumor Recognition in Wireless Capsule Endoscopy Images Using Textural Features and SVM-Based Feature Selection," in IEEE Transactions on Information Technology in Biomedicine, vol. 16, no. 3, pp. 323-329, May 2012., doi: 10.1109/TITB.2012.2185807.

[9] Accessmedicine.mhmedical.com. (2019). Harrison's Principles of Internal Medicine, 20e | AccessMedicine | McGraw-Hill Medical. [online] Available at: https://accessmedicine.mhmedical.com/book.aspx?bookid=2129 [Accessed 24 Jun. 2019].

[10] Sasaki, N. and Yamada, H. (2010). Preliminary study of capsule endoscopy in the small intestine of horses. Australian Veterinary Journal, 88(9), pp.342-345.

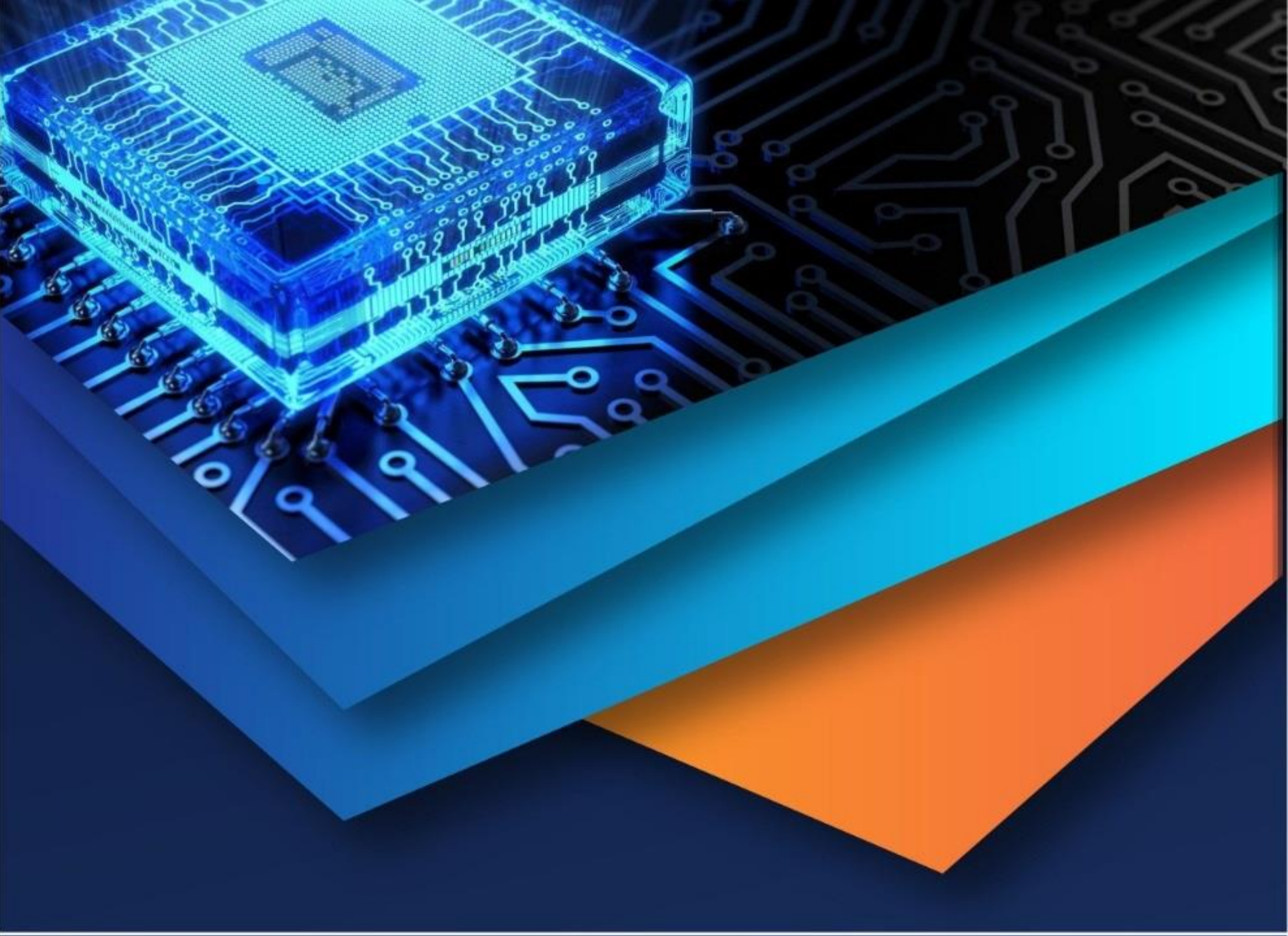
[11] Elsevier.com. (2019). Gray's Anatomy - 41st Edition. [online] Available at: https://www.elsevier.com/books/grays-anatomy/standring/978-0-7020-5230-9 [Accessed 14 Jun. 2019].

[12] Furnari, M., Ballardini, G., Savarino, E., Gemignani, L., Savarino, V. and Meroni, E. (2012). Sa1760 The Role of Wireless Capsule Endoscopy (WCE) in the Detection of Occult Primary Neuroendocrine Tumors. Gastrointestinal Endoscopy, 75(4), p.AB267.

[13] Ou, G. (2015). Effect of longer battery life on small bowel capsule endoscopy. World Journal of Gastroenterology, 21(9), p.2677.

[14] Slawinski, P., Obstein, K. and Valdastri, P. (2015). Emerging issues and future developments in capsule endoscopy. Techniques in Gastrointestinal Endoscopy, 17(1), pp.40-46.

[15] Meinhard T. Schobeiri, Fluid Mechanics for Engineers: A Graduate Textbook, Springer, Berlin, Heidelberg, 2010 Ed.



10.22214/IJRASET

45.98

IMPACT FACTOR:
7.129

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY