Research Journal of Recent Sciences ____ ISSN 2277-2502
Vol. **4(1),** 129-134, January **(2015)** *Res.J.Recent Sci.*

Simulation of Hydraulic Jump through Channels Junction Using the Flor 3D and Flunent Models

Zahedi Ali Akbar[1], Musavi Jahromi Seyed Habib[2], and Liravi Hassan[3]
[1]School of civil Engineering, Islamic Azad University, Central Tehran Branch, IRAN
[2]School of Water Sciences Engineering, Shahid Chamran University, IRAN
[3]School of Civil Engineering, Isfahan University, IRAN

Available online at: www.isca.in, www.isca.me
Received 6th January 2014, revised 23rd March 2014, accepted 17th June 2014

Abstract

This paper presents to analyze the current characteristics in channel's junction and their upstream and downstream based on hydraulic jump due to junction. In this case using two rectangular flume with 1 and 5 percent slope to production of current with different landing number in upstream of channels, double-width proportion of secondary channel to main channel, three proportion in discharge of secondary channel to total flow, and finally two total flows and connection angle of 90 degree, is considered. By comparing the result, one can find out various parameters affect on width leap and its distance of production location. In other word, when the size of total flow, proportion of secondary channel to total flow, the width proportion of main channel to secondary channel, and linear slope of two channels increases, the hydraulic jump width and its distance of production location could be increased. Generally, in 12 cases been analyzed, in some cases is noticeable, although in different cases is negligible. Also, the separation zone in all of cases could be observed. Furthermore, the FLOW3D could provide more ideal results than experimental model.

Keywords: Channels junction, hydraulic jump, Landing number, FLOW3D and FLUENT numerical models.

Introduction

Hydraulic jump is a fast variable flow which is in various applications. That is the suddenly switch of flow from over critical to under critical situation. In this process, the depth of flow in a short distance increases noticeably. It causes not only the considerable decrease of energy and aging, but also the considerable decrease of velocity. In this situation and with ratio of jump, the turbulence is observed over the water. When we get to end of the jump, the tension could be decreased and because of transformation of energy to heat, the water's energy goes down. The connection of the channels is a phenomenon which is existed in natural rivers, transmission and distribution of irrigation systems, drainage systems, and gathering systems[1,2].

This connection causes the fluctuation of flow and hydraulic jump. In point of connection, due to collision of two currents with different directions and make a novel current with various characteristics, the special hydraulic phenomena could be occurred. In the previous literature, the effect of different parameters on current characteristics is evaluated. However, there are a few researches on hydraulic jump caused by connection of channels.

Taylor calculated the depth of upstream and downstream of current in a channel. Also the newest research of subject has been done by Shabayek and his colleague. The main difference of these articles is in way of control volume selection. There are many assumptions to simplification of problem due to high complexity and various parameters[1].

The main experimental researches in this subject as follows: Bestand Reid studied on channels connection with angle of 15, 45, 70, 90 degree. They used a constant width for main and secondary channels (i.e. 0.15 meter). The current conditions in all of experiments were sub critical and landing number of channel was between 0.1 and 0.3. They also represented the variation of dimensionless parameters by curves. For example, the variation of $\frac{l}{s}, \frac{s}{w}, \frac{s}{w}$ in relation to Q_{bd} and secondary branch momentum to main branch momentum could be mentioned.

Also they observed that S/W_d and L/W_d could increase, if Q_{bd} and m increase. And by increasing of collision angle from 15 to 90, this variation could be signified. Another study was the comparison of width separation zone with other obtained values in different articles. They formulated the flow in connection channels using conformal mapping and obtained results for dimension of separation zone. Hager by formulation of continuous equations, momentum, and energy in connection channels location obtained a formulation for compaction factor in separation zone location as follows:

$$\frac{1}{\mu} = \frac{1+\sqrt{(1-\overline{Q}_{ud})(2-\overline{Q}_{ud})(1-\frac{2}{3}\cos\theta-\frac{1}{3}\cos^2\theta)+\frac{1}{9}\cos^2\theta}}{1+\frac{1}{3}\cos\theta} \quad (1)$$

He compared the amount of μ obtained by Best and Raid[3]. He inferred that the (1) for small angles has a good performance. However, if the angles increase the accuracy of this equation decreases. Chrustodoulou analyzed the hydraulic jump by using a model with collision angles of 90 and 17 degree and less width for secondary branch. In this case, the current situation in upstream of secondary channel and main channel were sub critical and over critical, respectively. Hsu et al checked the experimental flume with connection angle of 60, 45, and 30. Furthermore, they can obtained results about depth of upstream to downstream channels and plunged energy factor in sub critical current [4, 5, 6].

$$\cos \bar{\delta} = 0.149 + 0.912Q_{ud} \quad 0.1 < Q_{ud} < 0.9 \qquad (2)$$

Due to importance of problem which can be useful in designing of channel connection, it is crucial to have a new research on it. Analyzing of hydraulic jump in connection of channels based on reduction of flow's energy and protection of downstream equipment is necessary.

Consequently, the main purpose of this paper is the simulation of hydraulic jump in connection of channels using FLUENT and FLOW3D software.

Given that the accuracy and configuration mode have affected on the results from the analysis and problem convergence time and stability of the solution and also the computing time, hence configuration mode around sensitive places and locations that require extra attention, are more important. In this model has tried to identify these places and network quality and network congestion at those places will be higher. To software calibration has been used existing models. Twelve models were chosen and were performed for all sensitivity analyses. The desired main channel has 12 m length, 4/0 width and 6 m height. In the main channel path and at a distance of 4/4 meters from the beginning of the main channel, accessory channel with 5/1 m long, 4/0 wide and 6/0 height is connected with connector angle 90 ° to the main channel. In the analyzed models accessory channel's width and both channels' slope within have changed. Mentioned geometry in ICEM CFD and FLOW3D software were produced meshed shown in Figure-2[7-10].

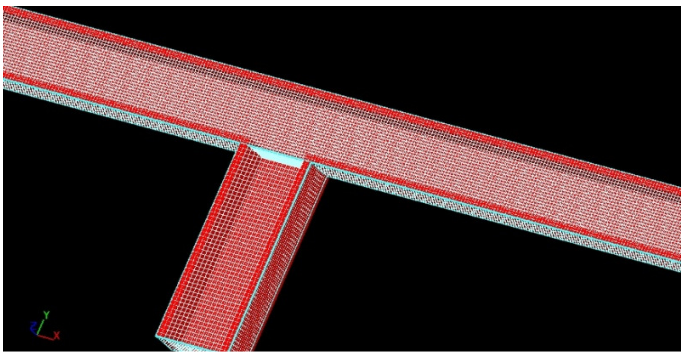

Figure-1
A view of the mesh

Case Study

In this study the effects of four variables on the flow properties of the channel connecting the hydraulic jump was investigated. These variables include (Q_d) total flow rate through two channels with amounts of 15 and 20 liters per second[10-15]. i. Ratio of accessory channel width to main channel width with amounts of 0.5 and 1. ii. Ratio of accessory channel's flow rate to total flow rate with amounts of 0.4, 0.5, and 0.8.

The longitudinal slope of the channel with the amounts 1 and 1.5 percent that was used to create flow with different landings in upstream of two channels. In hydraulic jump issue, characteristics 1-jump width, 2–jump distance from the bottom edge of junction, were examined which results are presented separately. Meanwhile, the parameters used are as follows:

Wj: Width of Hydraulic Jump (part of the channel width in downstream of the connection point at which the jump occurs.

Lj: distance of jump location from the bottom edge of junction.

Y: currents depths in different points of the main and accessory channel.

Width of Hydraulic Jump

Flow inters to the connection area from main and accessory channels and after merge, passes part of its energy through the compact area with supercritical state and decreases its depth with movement to toward downstream and hydraulic jump occurs at encounter with sub-critical flow in downstream.

In this scenarios, the separation zone is formed on the side of the main channel that accessory channel is connected to the main channel from same side. Therefore, the downstream flow rate is higher at the edge of the front wall and for this reason the phenomenon of hydraulic jump in the front wall of the main channel is more clearly evident. Part of the main channel width in downstream is called Wj where jump is clear. To evaluate this issue, the impact of different variables on the jump width is investigated. The effect of two channels slope, total flow rate and ratio of two channels width on hydraulic jump versus flow rate to total flow rate ratio are shown in figure (2) to (3) respectively. The results are obtained from FLUENT and FLOW3D software. In 8 following cases, the 90% of hydraulic jump width versus flow rate in FLOW3D software are higher than the results of FLUENT software. These results are more accurate, so this issue can be specified from graphs. Overall, the following results can be obtained of this graphs[7-15]: i. Hydraulic jump width decreases with decreasing flow rate, but its amount is very low. ii. The slope has an effective and important behavior on jump width, 1% and 1.5% are supercritical slopes for total flow rate of 15 and 20 liter per second and jump was possible in these slopes if the intersection phenomenon was not and the channel was direct.

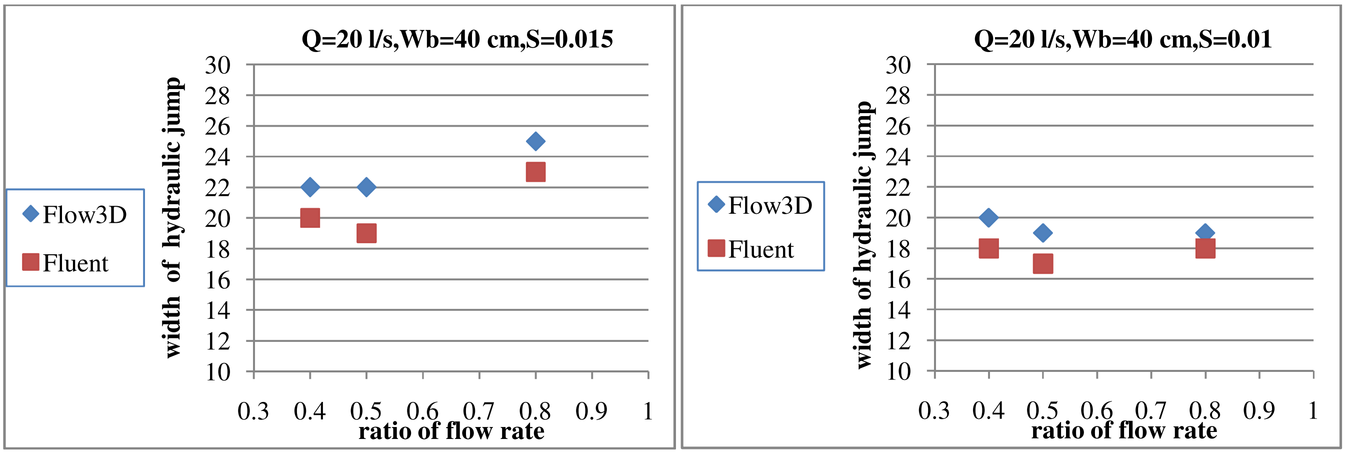

Figure-2

a) comparison of jump width ratio versus flow rate in the first, second and third scenario - total flow rate of 20 b) comparison of jump width ratio versus flow rate in the fourth, fifth and sixth scenario - total flow rate of 20

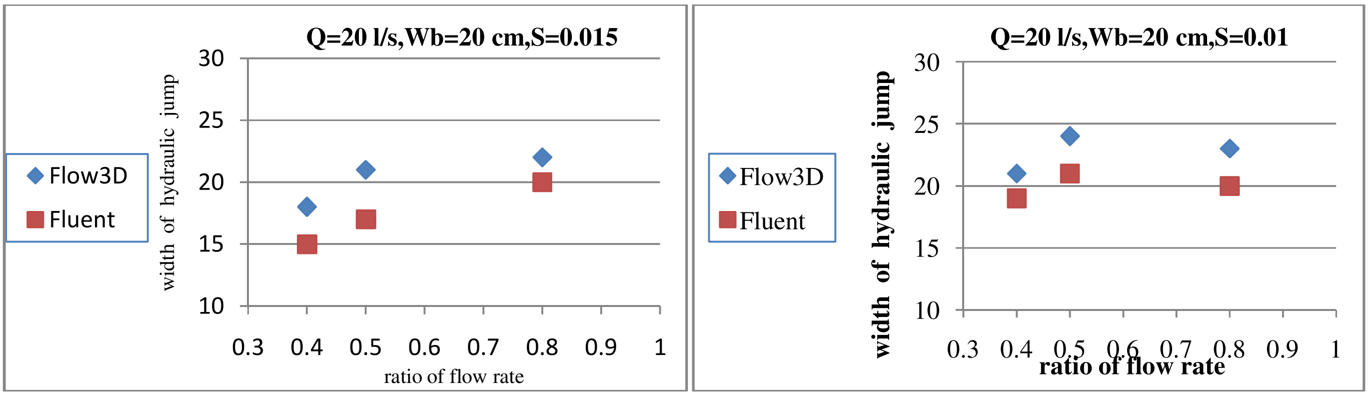

Figure-3

a) comparison of jump width ratio versus flow rate in the seventh, eighth and ninth scenario - total flow rate of 20 b) comparison of jump width ratio versus flow rate in the tenth, eleventh and twelfth scenario - total flow rate of 20

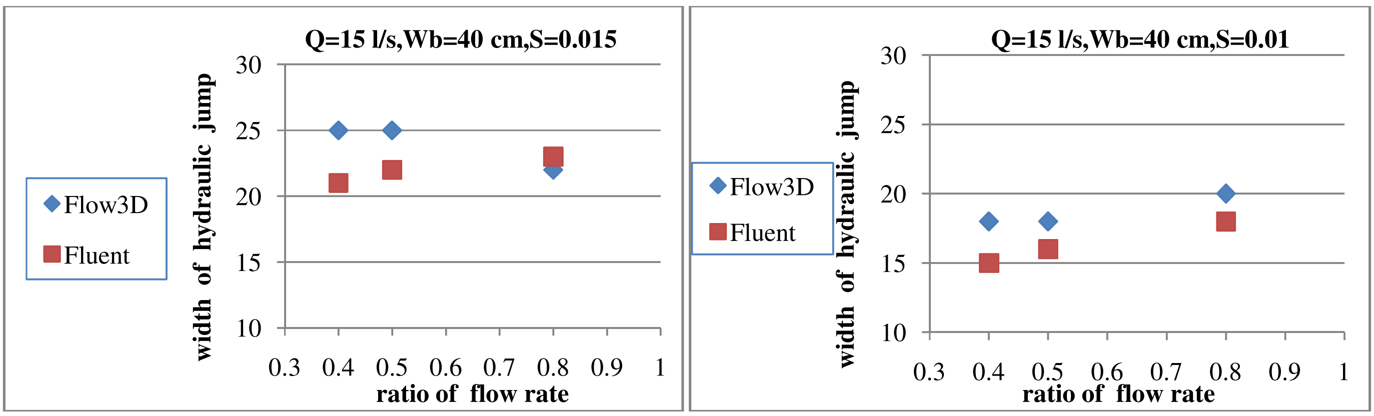

Figure 4

a) comparison of jump width ratio versus flow rate in the first, second and third scenario - total flow rate of 15
b) comparison of jump width ratio versus flow rate in the fourth, fifth and sixth scenario - total flow rate of 15

The width of the jump increases with increasing total flow rate. Its reason is reduction of the compression cross section with increasing flow rate. The current after more contraction in the compaction cross section, will has more disruption in its downstream and creates jump with higher width.

Reducing ratio of two channels width increases the width of the jump due to large reduction of compression cross section with reduction of ratio of two channels width. The ratio of two channels width in high flow rate (Qbd=0.8) has more effect on jump width.

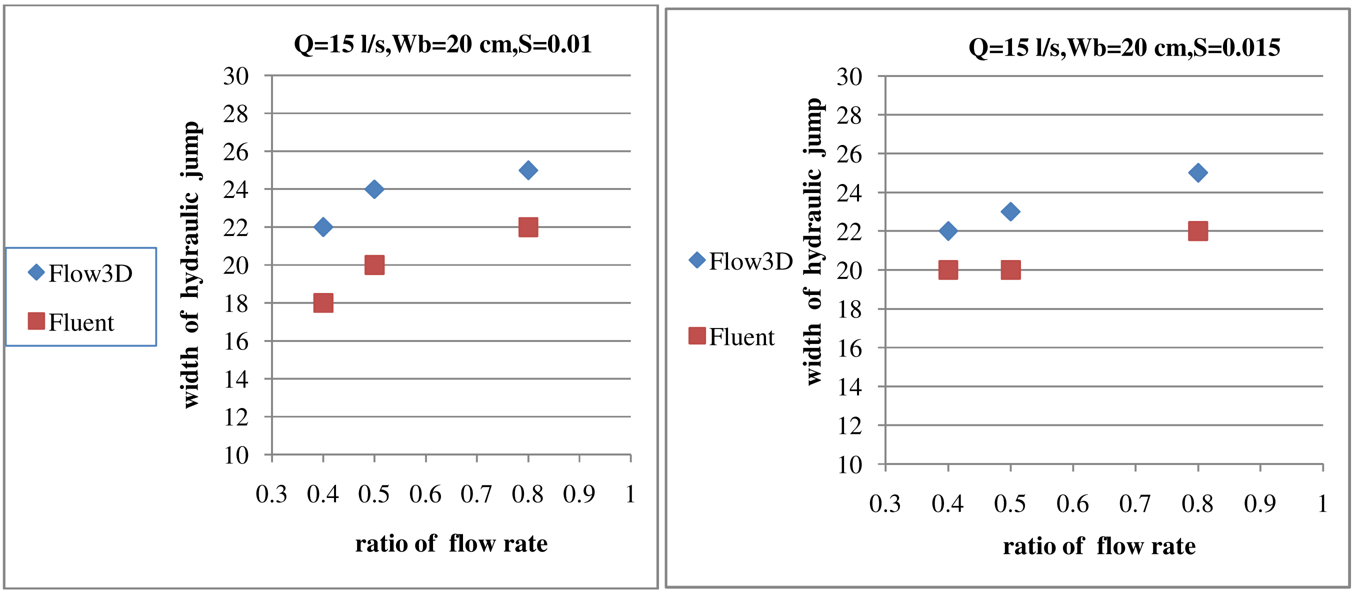

Figure-5

a) comparison of jump width ratio versus flow rate in the seventh, eighth and ninth scenario - total flow rate of 15 b) comparison of jump width ratio versus flow rate in the tenth, eleventh and twelfth scenario - total flow rate of 15

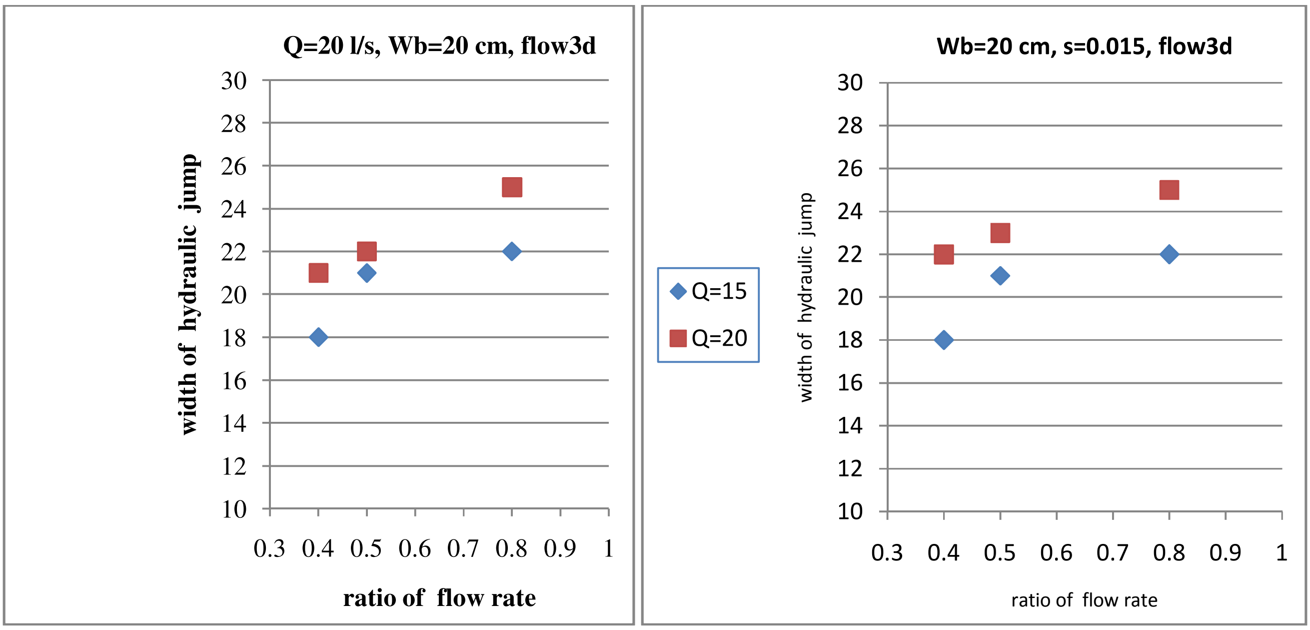

Figure-6

Comparison of jump width versus ratio of flow rate for channels' different slope

Jump distance from the bottom edge of junction

The following figures show effect of channel's slope, total flow rate and ratio of two channels width on jump distance from the bottom edge of junction (Lj) versus flow rate ratio respectively. The results are obtained from FLUENT and FLOW3D software for 6 initial scenarios shows in two flow rates of 20 and 15 liters per second. It should be noted that the downstream landing of main channel has a significant effect on Lj. Almost in all below cases, the values of jump distance from the bottom edge of connection versus flow rate ratio in FLOW3D software is greater than results of FLUENT software. However, this amount is very small and more precise results so that it can be detected of graphs.

Overall, the following results can be obtained of these graphs: i. With decreasing flow rate, Lj decreases. Its reason is that as flow rate increases, the upstream current velocity of hydraulic jump increases and causes push back of downstream sub critical flow and increase of Lj. ii. With increasing slope, Lj increases due to increasing landing of connection point's upstream current and transferring it to this point and it's downstream. As a result, the current velocity in upstream of the hydraulic jump is increased and increases Lj. iii. With increasing the total flow rate, Lj increases due to reduction of compression cross section. As a result, the current velocity in upstream of the hydraulic jump is increased by increases Lj.

Conclusion

In this study the effects of four variables on the current properties in the connecting channels, hydraulic jump and its characteristics were studied. These variables include: two total flow rate (Q_d), two width ratio (W_{bd}), three flow rate ratio (Q_{bd}) and two channel's longitudinal slope (S) that the results from it are presented.

Hydraulic jump width has a direct relation with ratio of flow rate (Q_{bd}) and total flow rate (Q_d). Slope effect on the jump width is different. It has enormous effect on the jump width at the slopes of 1 and 1.5 percent due to the high landing and the probability of a supercritical current. Width ratio of the two channels only has significant effect on jump width in high ratios of flow rate. In ratio of flow rate higher than 0.7, reducing width ratio of two channels increases the width of the jump. Variables Q_{bd}, Q_d, S and W_{bd} have most effect on ratio of jump distance to bottom edge of junction (L_{hj}) respectively and among of these variables, W_{bd} has opposite effect on Lj. Increase in channels slope and consequently increasing the upstream landing of two channels and decreasing channel width ratio (W_{bd}), increases the hydraulic jump's conjugate depths ratio (depth before and after jump), and are produced stronger jump. FLOW3D software output results are far more accurate and closer to the experimental results, which perhaps its reason is that FLOW3D model is purely hydraulic and for commercial uses and has not the complex setting parameter of FLUENT model.

Reference

1. Taylor E.H, Flow Characteristics at Rectangular Open-Channel Junction, Trans. ASCE, 109, 893-912 **(1944)**
2. Shabayek S., Steffler P. and Hick F., Dynamic Model for Subcritical Combining Flow in Channel Junction, *J. Hydr. Engrg, ASCE,* **128(9),** 821–829 **(2002)**
3. Best J.L., Reid. I, Separation Zone at Open-Channel Junctions, *J. Hydr. Engrg, ASCE,* **110(11),** 1588–1594 **(1984)**
4. Hager W.H., Discussion: Separation Zone at Open-Channel Junctions, J. Hydr. Engrg, , ASCE, 529–543 (**1987**)
5. Christodoulou G.C, Incipient Hydraulic Jump at Channel Junction," *J. Hydr. Engrg,* ASCE, **119(3),** 409–421 **(1993)**
6. Hsu. C.C, Lee. W.J. and Chang. C.H, Subcritical Open-Channel Junction Flow, *J. Hydr. Engrg,* ASCE, **124(8),** 847–858 (**1998**)
7. Bradbrook K.F., Lane S.N., Richard K.S., Biron P.M., Roy A.G., Investigation of Controls on Secondary Circulation in a Simple Confluence Geometry Using a Three-Dimensional Numerical model, J. Hydrol. Process, John Wiley and Sons. Ltd, **12,** 1371-1396 **(1998)**
8. Ansys ICEM CFD, Ver. 14.0, User Manuals, **(2007)**
9. Ansys Flunet, Fluid Dynamic Ver.14.0,User Manuals, **(2007)**
10. Weber L.J., Schumate. E.D. and Mawer N., Experiments on Flow at a 90^0 Open-Channel Junction, *J. Hydr. Engrg, ASCE,* **127(5),** 340–350 (**1998**)
11. Muhammad Usman and Ikufumi Tomimoto, The Aging Population of Japan: Causes, Expected Challenges and Few Possible Recommendations, *Res. J. Recent Sci.,* **2(11),** 1-4 **(2013)**
12. Mohammad Aghaei, Amin Asadollahi, Maryam Tonekaboni, Nasim Tajasom and Samin Abbasi, Investigating the Impact of Store Brand Price-Image and Retailer Equity Dimensions on ETKA Chain Store Customer's Purchase Intention, *Res. J. Recent Sci.,* **2(11),** 5-11 **(2013)**
13. Rosman Md. Y., Shah F.A., Hussain J. and Hussain A, Factors Affecting the Role of Human Resource Department in Private Healthcare Sector in Pakistan: A Case Study of Rehman Medical Institute (RMI), *Res. J. Recent Sci.,* **2(1),** 84-90, **(2013)**

14. Movahedi M.M., A Statistical Method for Designing and analyzing tolerances of Unidentified Distributions, *Res. J. Recent Sci.,* **2(11),** 55-64, **(2013)**

15. Elahe masomi, Amir Eghdami, Mohsen Derakhshan asl, Saeid Ashore and Peyman Ghanimat, The Relationship between Organizational Climate Dimensions and Corporate Entrepreneurship (Case Study: Meshkinshahr Payam Noor University, Iran), *Res. J. Recent Sci.,* **2(11),** 107-113, **(2013)**