







Fig. 4 Arithmetic roughness values

Regarding the formed copper sheets surfaces, it is observed that the surface sheet is smooth. There are no metal fragment at the deformed surfaces compared to the steel and the aluminum in some previous studies [1,2]. The initial roughness Ra for all specimens in the undeformed area is  $1.53 \mu\text{m}$ . The percentage of the arithmetic mean profile deviations was determined with respect to the initial roughness of the workpiece before the forming process. The calculated percentage for the three specimens SP1, SP2 and SP3 are respectively 52.13%, 52.38% and 62.68%.

By analyzing the percentage gaps, it seems that the roughness of obtained copper sheets using a lubricant 3 which contains 88% of water and 12% of Oil leads to poor surface state. On the other hand, the lubricant that has the largest density had the better surface quality.

#### IV. CONCLUSION

At the contact area between the forming tool and the sheet metal, a friction will occur during the SPIF process which induces a local heating. To reduce the temperature level, it is necessary to use a lubricant. In our investigation, three lubricants are used to detect their influence on the forming forces and the surface roughness, for SPIF process of copper sheet. From this work, some conclusions are drawn:

- The type of lubricant does not affect the forming time despite the increasing in the step time increment.
- The use of lubrication prevents the appearance of metal fragments. Otherwise, the type of lubricant has a significantly impact in the maximum values of axial and radial forces. The lubricant with lower density reduces the axial force.
- The use of lubrication improves the quality of manufactured surfaces. Moreover, the lubricant with lower density has the highest value of surface roughness.

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**Mariem Dakhli** received her engineering degree in Mechatronics Engineering from National Engineering School of Sousse, Tunisia, in 2013. She is currently a Ph.D. student at Department of Mechanical Engineering, University of Sousse, Tunisia. She is currently a Ph.D. student at Department of Mechanical Engineering, University of Sousse, Tunisia. Her research interest is Incremental sheet forming.

**Atef Boulila** is a teacher-researcher and Master-Assistant at the National Institute of Applied Sciences and Technology (INSAT). He received the Ph.D degree in mechanic from National Engineering School of Tunis and University of the Mediterranean (Aix-Marseille II, France). He teaches different courses for the specialties of industrial maintenance and industrial computer science. He participated in the preparation of national competitions input to engineering schools in industrial science and technology. He leads and supervises research work on the shaping of structures by plastic deformation and the Digital Plant & PLM.

**Zoubair TOURKI** is currently the director General of University Renovation. Previously, he is director of the National School of Engineering of Sousse (ENISO) since 2011. He is Professor in Mechanical Engineering, graduated from the University of Metz (France). He received the M.S.T. Degree in Mechanical Engineering option CAD/CAM in 1990 from the University of Metz (France). In 1999, he got his Qualification as Associated Professor in France (Number: 9926084020). He obtained his Ph.D. in Engineering Science Mechanical in 1995 from the University of Metz. He received his habilitation Universitaire in Mechanical Engineering in June 2004 from National Engineering School of Monastir (Tunisia). He had a Post-Doctoral Federal Fluminense in the University of Brasil (Rio de Janeiro- Brasil) in 1995-1996. He participated in different European Projects like HiT4med / ACM Master pro in Applied Computational Mechanics ENISO-Ingolstadt (European Accreditation of Engineering Programmes EUR- ACE). His research activities are devoted to Shape memory alloys and manufacturing process.

**Pierre Yves Manach** is the director of the research laboratory named Institute de Recherche Dupuy de Lôme (IRDL), University of South Brittany in France. He obtained his PhD in 1993 in the National Polytechnic Institute of Grenoble in France and defended an Habilitation of Researchers Management at the University of South Brittany on the topic of "Constitutive laws and forming of metallic materials". He is now full Professor in Mechanical and Material Engineering. He has published more than 50 articles in international journals and supervised 12 PhD students. His research activities are devoted to plasticity and damage of metallic materials, with applications to various multi-step forming processes.