Study Effects of Stamping Parameters on the Formation of a Car Hood Inner Panel

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Abstract. In this study, the authors study on structural optimization of a car hood inner panel and the stamping process quality in order to obtain a proper design of the hood inner panel for manufacturing. In this paper, the authors present an optimization study of process parameters of stamping process of the hood inner panel. The effects of two process parameters such as blank holding force (BHF) and the stamping speed on the formation of the hood inner panel were investigated by using computer aided engineering (CAE) simulation inside ETA/Dynaform software. The results show that with small BHF value, the deformation of the hood inner panel is insufficient and the wrinkle occurs in some areas on the part. On the other hand, when the BHF is high, the deformation is too large which results in wrinkle and crack. Similarly, when stamping at slow speed, the plastic deformation of the hood inner panel is insufficient and cause wrinkle on the part. By increasing stamping speed, the forming quality of the part is improved and become stable. It is found that when stamping with BHF of 500 Ton and stamping speed of 30 mm/s, good quality of the hood inner panel is achieved in this study.

Keywords: Plastic Deformation, Process Optimization, CAE Simulation, Hood inner panel

1 Introduction

Recently, people face the lacking and shortage of the fosil fuel. Moreover, alternative energy resources such as solar cell energy, bio energy, etc. are still too expensive to replace the fosil fuel using in cars. It is necessary to reduce the weight of the car in order to reduce the fuel consumption. In order to reduce the weight of the car, it is necessary to optimize the car structure. Especially, the car body structure which consists of many thin sheet metal stamping parts. The car engine hood inner panel is a thin sheet metal stamping part which has some specical characteristics such as large dimension, shallow draw, and good surface quality. It is requires for this part to have light weight but enough strength to protect the engine. In order to reduce the weight of the hood inner panel, people design it with many holes and pockets together with making up the supporting ribs and stiffeners to strengthen the panel structure. However, introducing supporting ribs and stiffeners to the hood inner panel which cause suddenly changes in curvature of the panel surface. Consequently, the wrinkle and crack is prone to occur at these areas during stamping process. In addition, since the drawing depth of the stamping part is shallow, the stretching deformation in the large and flat areas is insufficient for plastic deformation. This will cause large springback together with the wrinkle on the finished stamping parts.

Many researches have been published in improving the stamping quality of thin sheet metal parts similar to a car engine hood panel. Chen and Liao [1] utilized finite element method (FEM) simulation for investigating the folding effects occurs during forming of a motorcycle fuel tank. In addition, they provided modification of die face model which eleminates the folding defects on the forming part. Later on, this group reported effects of various addendum shapes on stamping quality of an engine hood panel by combination of FEM simulation and actual stamping experiments [2]. They also reported a design flow chart for the research and developement of a car engine hood panel. Qiu [3] et al. studied the effects of various blank shapes on the stamping quality of an engine hood panel and proprosed cost effective blank size for successfully stamping of an engine hood panel. Chen [4] et al. reported the optimization of process parameters in forming of an engine hood inner panel. In addition, they demonstrated the possibility to use the aluminum alloy instead of steel alloy used for engine hood inner panel in order to reduce the weight of the part. Masahiko [5, 6] investigated wrinkle behaviour of press forming of auto body panel made of aluminium alloy. They proved a low tooling fee and production cost when using aluminum alloy sheet for the stamping parts using for vehicles. Many researches have reported the feasibility of using aluminium alloy for both inner and outer automotive panels [7-9]. However, the challenges when using aluminium alloys for automotive body stamping parts are poor formability and large springback during cold stamping process [10]. Therefore, besides finding the alternative light weight materials for the automotive stamping parts, the optimization of the its structure is still highly demanded. Since the automotive body structures are different from model to model. Therefore, it is difficult to find a global optimal shape structure to fit all the model. Hence, the optimization process can be done for a specific case or similar parts.

In this study, the authors study the optimization of the structure of an automotive hood inner panel using Altair Optistruct software in order to reduce the weight of the hood inner panel, and then studying on the stamping formability of the designed part is carried out. In this paper, the authors present the second one which investigates the effects of the blank holding force (BHF) and the stamping speed on the formability of the hood inner panels by using ETA/Dynaform simulation software. From the simulation results, the suitable BHF and stamping speed is found.

2 Methodology

Fig. 1 (a) shows the finshed hood inner panel studied in this paper. It is a thin sheet metal part which consists of many ribs and beads, and complex stamping features to enhance the bending strength and toughness. Fig. 1 (b) shows the stamping part before cutting holes inside the panel. Since this part is shallow drawing, therefore, the tension stress is not enough for plastic deformation in large areas with low curvatures or flat. Insufficient deformation causes not only the wrinkles but also large springback will occurs. Consequently, it decreases the quality of the stamping part. Therefore, optimization of stamping process parameters to address these issues is studied. Fig. 1 (c) shows the blank for the stamping. The blank size is: 1750 x 1600 (mm). The thickness is 1.2 (mm). The blank has chamfer at two lower corners to reduce the plastic deformation in this areas.

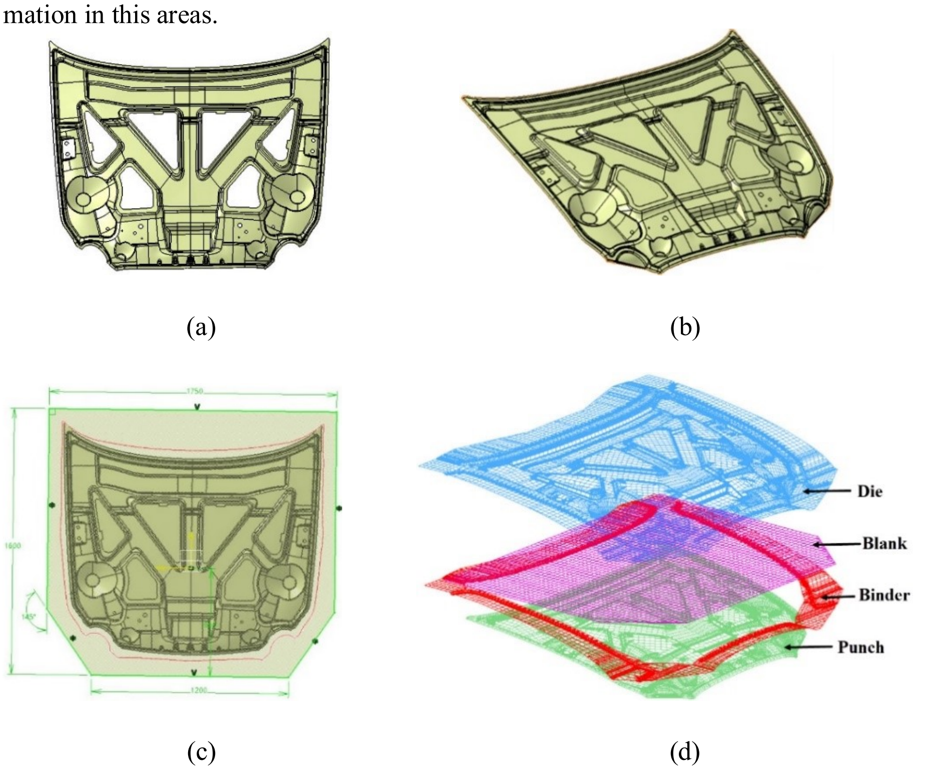

Fig. 1. The hood inner panel for study stamping process: (a) Finished model; (b) 3D stamping model; (c) Blank size; (d) FEM model for simulation

In this paper, the authors study the effects of the BHF and the stamping speed on the formability of the part. The BHF was varied from 150; 200; 300; 400; 500; 700; 900 (Ton). The stamping speed was varied from 14; 22; 26; 30; 35; 40 (mm/s). The blank material was SPCC (JIS G314) which the material properties was presented in [11].

3 Results and discussions

Fig. 2 shows the formation results of the hood inner panel stamped with different BHF from 150 to 900 Ton. It is found that the crack does not occur in all the cases. This is because the stamping features are shallow. Therefore, the strain of the panel is not enough for occuring cracks. It is obvious that the wrinkle occurs either inside or outside of the cutting line of the hood inner panel. It is noted that the cracks and/or wrinkles occurs outside the cutting line does not affect the quality of the stamping parts since it is cut away after stamping. When BHF is equal to 150 Ton, the wrinkle occurs in region A and C, and it may appear in region B. This is because these regions have the the large change of surface curvature from flat areas to high curvature features. During the stamping process, small BHF results in small strain in these areas. Therefore, the plastic deformation is insufficient in these regions, and causes the wrinkles. When the BHF increase to 200 to 500 Ton, the stamping quality is improved. The wrinkle is less in regions A and C, and the formation in region B is safe and better. Especially, when the BHF equals to 500 Ton, the stamping quality is much improved. The wrinkle does not occur in region C and less occurs in region A. In addition, the safe stamping area is increased in the region D as seen in the Fig 2 (e). This is because increasing of BHF results in increasing of the strain and causes more uniform plastic deformation, especially in the shallow and flat areas. When the BHF equal to 700 and 900 Ton, the severe wrinkle occur in the region A and E, and the crack tends to be occurred in region E. This is because when BHF is too high, the strain is much increased in the high curvature and narrow ribs as in region E in Fig. 2 (f). This results in severe wrink and crack occurs in this region.

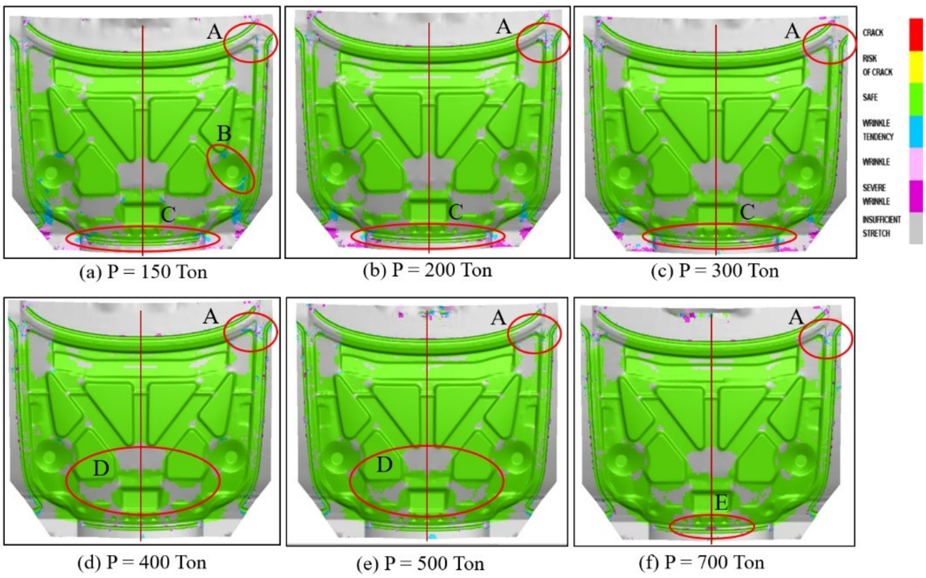

Fig. 2. Forming of the hood inner panel stamped with different blank holding forces

Besides surface quality, another important criteria for evaluating quality of a stamping part is the thickness distrubution after stamping. It is obvious that the more uniform thickness, the better quality the stamping part. Fig. 3 shows the thickness distribution of the hood inner panel stamping with the different BHF from 150 to 900 Ton.

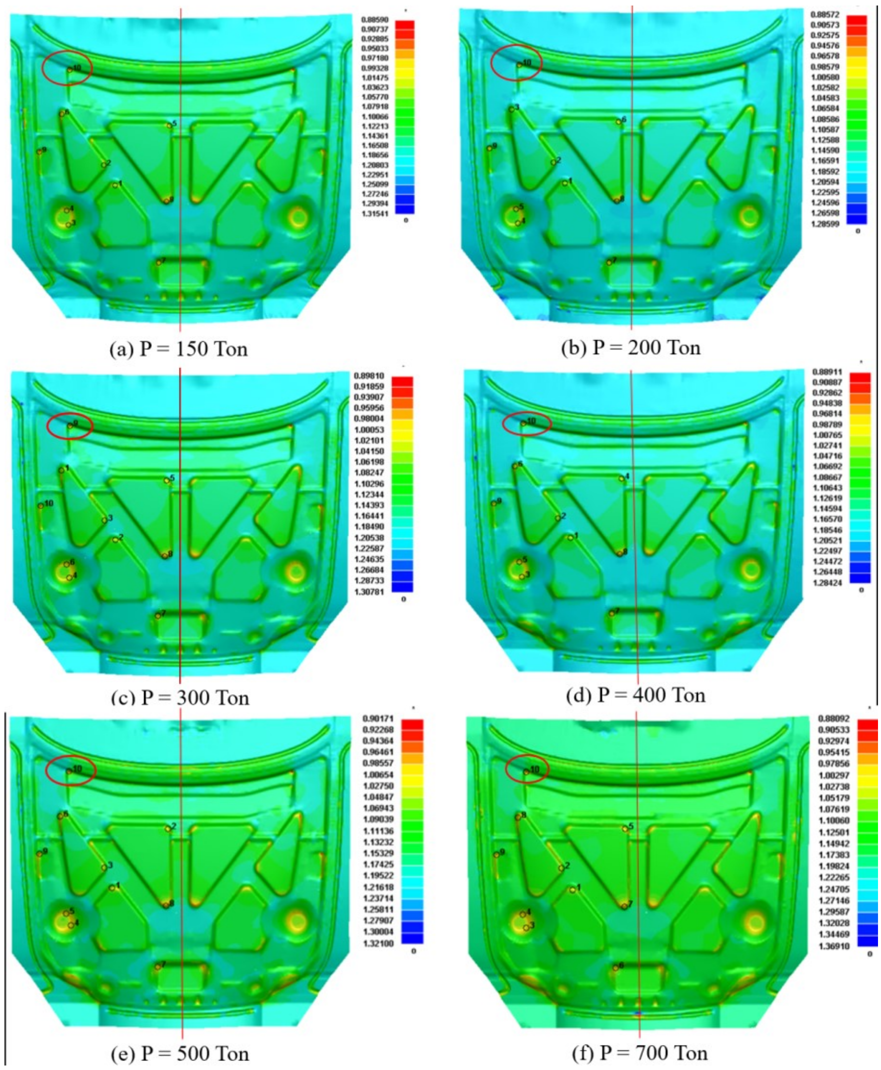

Fig. 3. Thickness distribution of the hood inner panel stamped with different blank holding forces

It is clear that the higher BHF, the average thickness of the stamping part in smaller. It is also found that when the BHF equal to 500 Ton, the thinnest point on the stamping part is 0.90171 which is greatest as compared with all the remaining cases. However, the thinnest point on the stamping part may not be appropriate evaluation since the thinnest point can be outside of the cutting line, which doesnot affect the quality of the stamping part. Therefore, it is important to evaluate the thickness distribution inside the cutting line of the stamping part. In order to evaluate the thickness distribution inside the cutting line of the stamping part, ten thinnest regions on a stamping part were choosen to analyze. In each of these regions the thinnest point was determine and measure the thickness of that point. Then, for each stamping part with a BHF value as shown in Fig. 3, we analyze ten points representative for ten thinnest regions on the part. For each BHF case, we calculate the standart deviation and the probability density function of the thickness distribution of these ten points as following equations:

$$\sigma = \sqrt{\sigma^2} = \sqrt{\sum_{i=1}^{N} \left(\frac{X_i - \mu}{N} \right)^2} \tag{1}$$

$$f(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2} \right) \tag{2}$$

Whereas, X_i is the thickness of the part at point *i,* μ is the everage thickness of the ten points, σ is the standard deviation of the thickness distribution, and f is probability density function of the thickness distribution.

Fig. 4 shows the graph of the normal probability density function of the thickness distribution of the ten analyzed points on each stamping part with different BHF. It is found that for all BHF value, the average thickness of the thinnest region of the stamping part is greater than 0.95 mm. From the normal distribution of the thickness of the

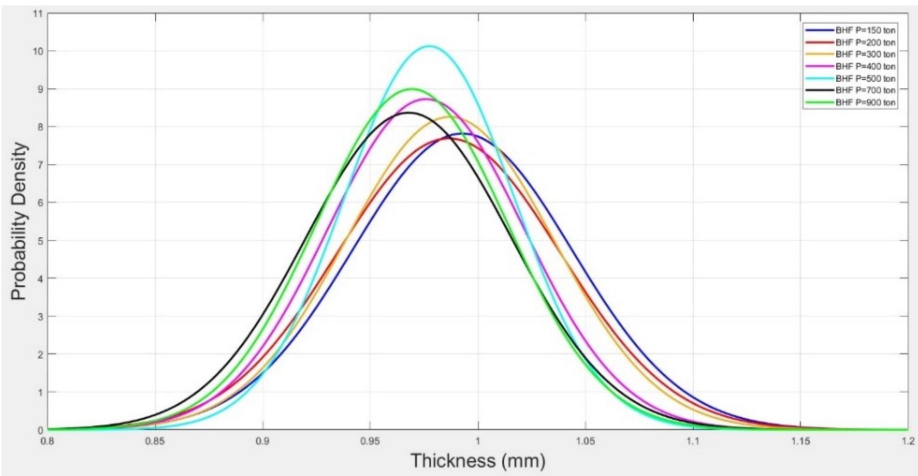

Fig. 4. Thickness distribution of ten thinnest regions on the hood inner panel stamped with different blank holding forces

ten thinnest regions, it is obvious that when the BHF equal to 500 Ton, the thickness of the stamping part is the most uniform. The average thickness of the ten analyzed points is μ = 0.978 mm and the standard deviation is σ = 0.04 when the BHF equal to 500 Ton. From the above analysis with different BHF values, it is found that when BHF equal to 500 Ton, the stamping part with best quality and most uniform thickness was achieved. Therefore, the BHF of 500 Ton was choosen to investigate the effect of the stamping speed on the quality of the stamping part.

Fig. 5 shows the formation results of the hood inner panel stamped with the different stamping speed from 26 to 40 mm/s. The BHF is 500 Ton and kept constant for all the cases. It is found that when the stamping speed smaller or equal to 26 mm/s, the severe wrinkle occurs in the region I and II which affect the quality of the stamping part. It also found that when the stamping speed equal or greater than 30 mm/s, the stamping process result is stable and the change is negligible. Most of the wrinkle occurs outside of the cutting line which does not affect the quality of the stamping part. It seems that when the stamping speed equal to 30mm/s the quality of the stamping part is better than when the stamping speed equal to 35mm/s or 40mm/s as seen in the Fig. 5 (d, e, f,).

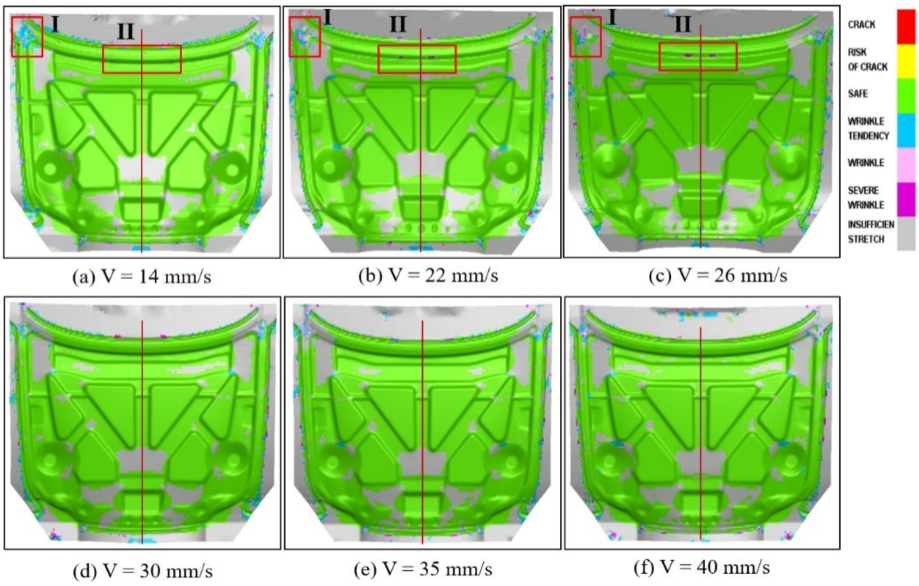

Fig. 5. Forming of the hood inner panel stamped with different speeds, the BHF is 500 Ton

In this study, it is found that when the BHF equal to 500 Ton, and the stamping speed equal to 30mm/s, the best quality of the stamping part was achieved. Fig. 6 shows the forming limit diagram (FLD), the thickness distribution and stress distribution of the stamping part when the BHF equal to 500 Ton, and the stamping speed equal to 30mm/s. The thinnest point inside the cutting line of the stamping part is 0.956 mm. It is found that average stress on the stamping part is over 220 MPa which is greater than ultimate tensile strenght of SPCC material. This implies that the stamping part is completed plastic deformation. However, insufficient stretch areas (large flat areas) still exist on the stamping part. Insufficient stretch area might cause the spring back issue on the stamping part. There are several methods to diminish these insufficient stretch areas such as adding the bead or rib with suitble geometry and curvature on the part, or adding draw bead on the die. This problems is under studying and will be published in near future.

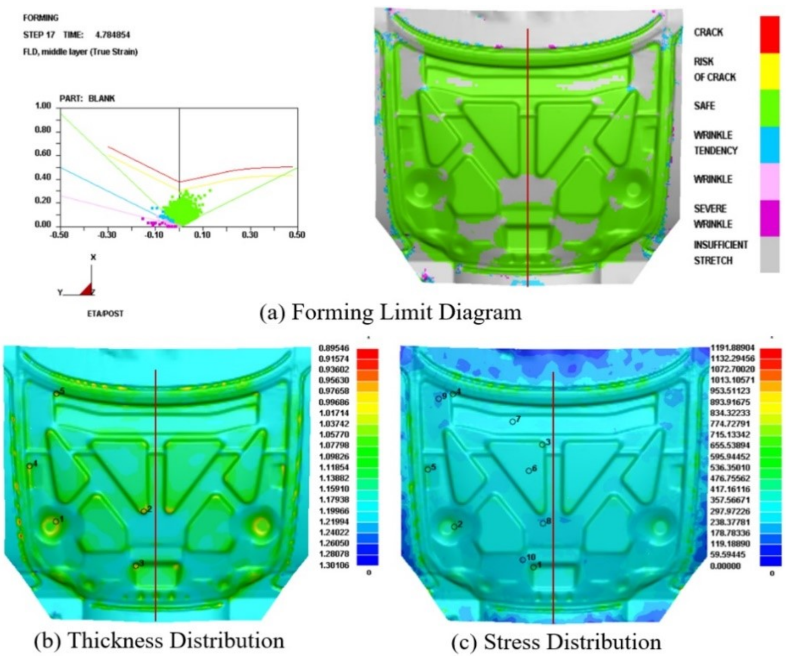

Fig. 6. (a) Forming limit diagram, (b) thickness distribution, (c) stress distribution of the hood inner panel stamped with BHF of 500 Ton and stamping speed of 30 mm/s

4 Conclusion

In this paper, the authors study on optimization of process parameters in stamping process of a car hood inner panel using CAE simulation inside ETA/Dynaform software. Two process parameters including blank holding force and the stamping speed were studied to evaluate the forming characteristics of the hood inner panel. It is found that stamping with either small BHF value or too high BHF value, results in low quality of stamping part, and wrinkles or/and cracks will occurs. Only stamping with proper BHF value, good quality of the hood inner panel is obtained. Likewise, stamping at slow and insufficient speed, also results in wrinkles occuring on the part which decreases the forming quality. The forming quality is improved and become stable when increase the stamping speed over 30 mm/s. In this study, It is found that stamping with BHF of 500 Ton and stamping speed of 30 mm/s results in good quality of the hood inner panel.

References

1. Chen F K and Liao Y C 2007 Journal of Materials Processing Technology 192-193 200-203.
2. Chen M Z, Wang S W, Lin C I, and Chen F K 2017 Journal of Physics, Conference Series, Volume 896, 012121.
3. Qiu H, Huang Y and Liu Q 2007 Journal of Materials Processing Technology 187-188 140-144.
4. Chen J, Lan F, Wang J, Wang Y 2008 Global Design to Gain a Competitive Edge (Berlin: Springer), p. 529.
5. Masahiko J and Yoshinori S 2000 Journal of Materials Processing Technology, 5(1) 51–60
6. Masahiko J and Yoshinori S 2006 Journal of Materials Processing Technology 34 (7) 35–39.
7. Liu J, Gao H, Fakir O E, Wang L and Lin J, 2015 MATEC Web of Conferences.
8. Bariani P F, Bruschi S, Ghiotti A, and Michieletto F 2014 Procedia Cirp 18, 68.
9. Jinta M, Sakai Y, Horie S, Oyagi M, Matsui K, and Hasegawa Y 2001 JSAE Rev. 22, 84.
10. Zhou J, Wang B, Lin J, and Fu L 2013 Arch. Civ. Mech. Eng.13, 401.
11. The-Thanh L, Tien-Long B, The-Van T, Duc-Toan N. 2019. Advances in Mechanical Engineering. August 2019. doi:10.1177/1687814019872674