CHAPTER 9

Results and Discussions

9. Results and discussions:

As discussed in the previous chapters, the deformation over the cup wall (called flow forming in this text) is conducted by the dies made of Inconel-600. It is also discussed that main objective of the study is to identify the extent of deformation that can be given to the material in single stage of drawing. This study may help to decrease the number of stages in deep drawing the automobile components e.g. a typical drum clutch is usually formed in 9 redrawing stages followed by 3 ironing stages in cold condition. By decreasing the number of stages, the manufacturing of these drums can be made economical. Test specimens of variable diameters from a 2mm thick rolled extra deep drawn steel sheet are prepared. A special fixture is prepared for lathe to cut these specimens. With the help of induction heaters as shown in Fig 4.7, these blanks are heated to various temperatures 200^0C, 400^0C, and 600^0C . Inconel die is also heated simultaneously. As mentioned in chapter 6, by increasing temperature, there will be increase in coefficient of friction. This friction is controlled by applying a high temperature lubricant called 'Molycote'. During the experimentation it is observed that this lubricant is to be applied over the dies in the cold condition, otherwise due to the appearance of excessive fumes, die area may catch fire. It is observed that, between 200^0C and 400^0C temperature this lubricant is highly effective. Tests are performed at 3 different clearances between punch and die. Cups drawn in the experimentation with variable clearance and at different temperature are shown in Fig. 9.1 to 9.8. It can be seen in Fig. 9.1 and 9.2 that with 40% reduction given to the material fracture appears very early. Fig 9.1 shows partially drawn cups at 600^{0}C. When the blank diameter was 62mm fracture appears in the drawn cup as shown in Fig 9.2. As it can be observed from figure 9.3 to 9.5 that with 25% reduction as temperature increases deeper cups can be drawn. But due to blue brittle phenomena 65mm diameter blank fractures at 600^{o}C because this temperature is transition temperature from blue brittle to elastic plastic. With 10% reduction given to material the process is more or less deep drawing with excessive ironing. So naturally thickness distribution is much uniform in this case.

Fig. 9.1 Cups at 40% reduction at 600^{0}C

Fig.9.2 Fracture at 40% reduction

Fig. 9.3 Cups with 25% thickness reduction and at 200^0C

Fig. 9.4 Cups with 25% thickness reduction and at 400^0C

Fig.9.5 Cups with 25% thickness reduction and at 600^0C

Fig. 9.6 Cups with 10% thickness reduction and at 200^{0}C

Fig. 9.7 Cups with 10% thickness reduction and at 400^{0}C

Fig. 9.8 Cups with 10% thickness reduction and at 600^{0}C

Load displacement graphs under various conditions of temp, blank diameter and % reduction are given in Fig 9.9 to 9.15. As it can be observed from this graph (as recorded by data acquisition system) that at a temperature close to 400^{o}C load requirement to draw the material suddenly increases. This is due to appearance of blue brittle phenomena in the material which increases the dislocation density of the material making it very strong. When the temperature increases further, the load requirement to draw the material decreases. This is primarily due to appearance of plasticity or decrease in mean flow stresses. It can be observed that middle portion of these cups is more or less flat because during this period material is getting deformed plastically in the wall region (similar to backward extrusion). Sudden decrease in the punch load indicates fracture as observed in fig 9.14. It is understood that by increasing the blank diameter at a fixed temperature larger loads will be required to draw the material (Fig 9.10 and 9.14). It can be observed from the Fig 9.15 that by keeping the same blank diameter and temperature of drawing there will be an increase in the load requirement because more energy will be required in deforming the material in the wall region.

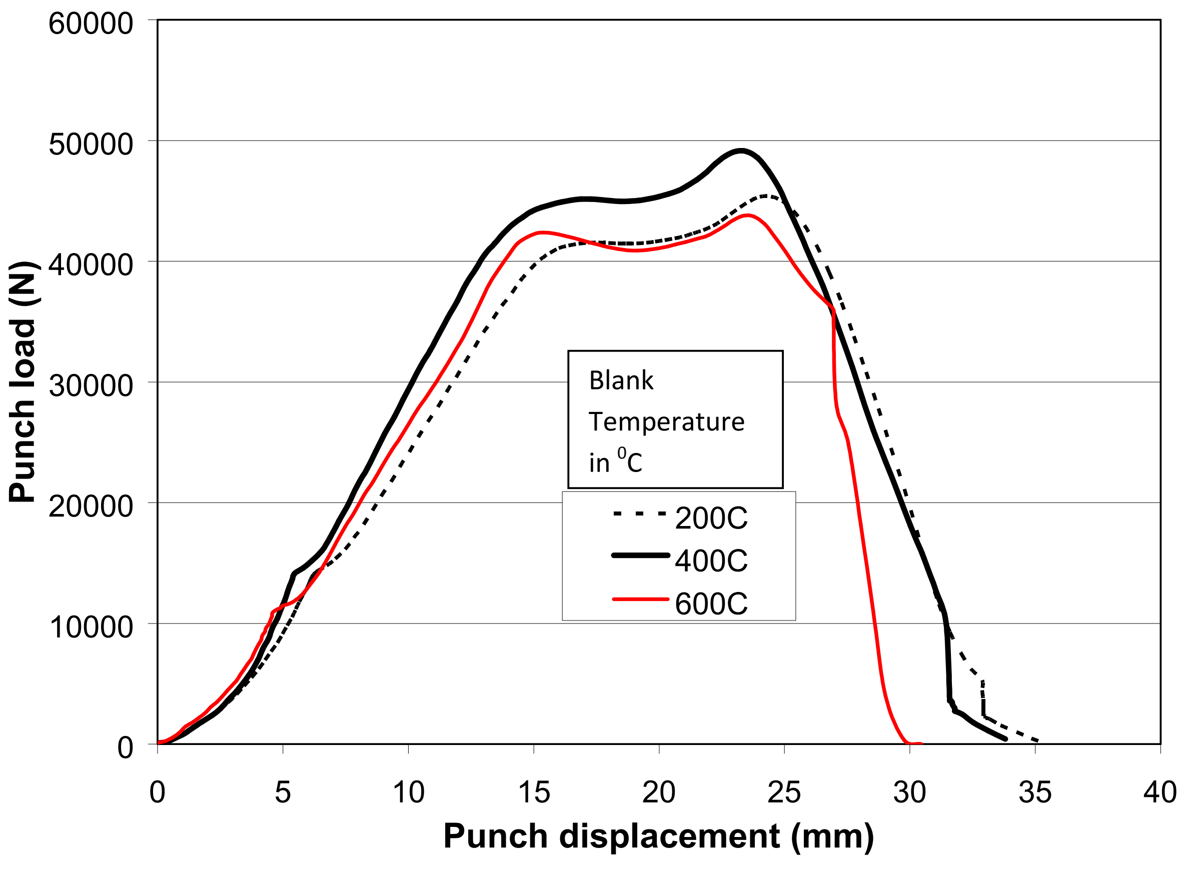

Fig. 9.9 Punch load Vs displacement graph from the data acquisition system at different blank temperature of 60 mm diameter blank with 25% reduction in thickness

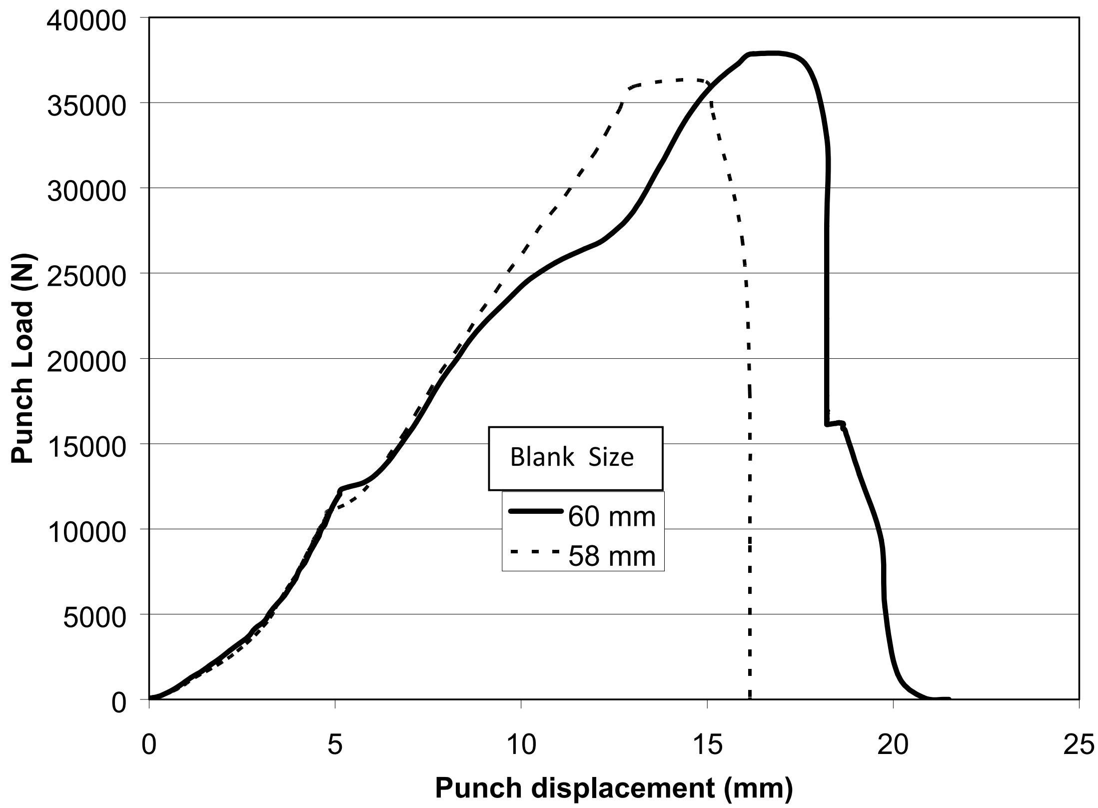

Fig. 9.10 Punch load Vs displacement graph from the data acquisition system at different blank diameters with 40% reduction in thickness and at 600^{0}C blank temperature

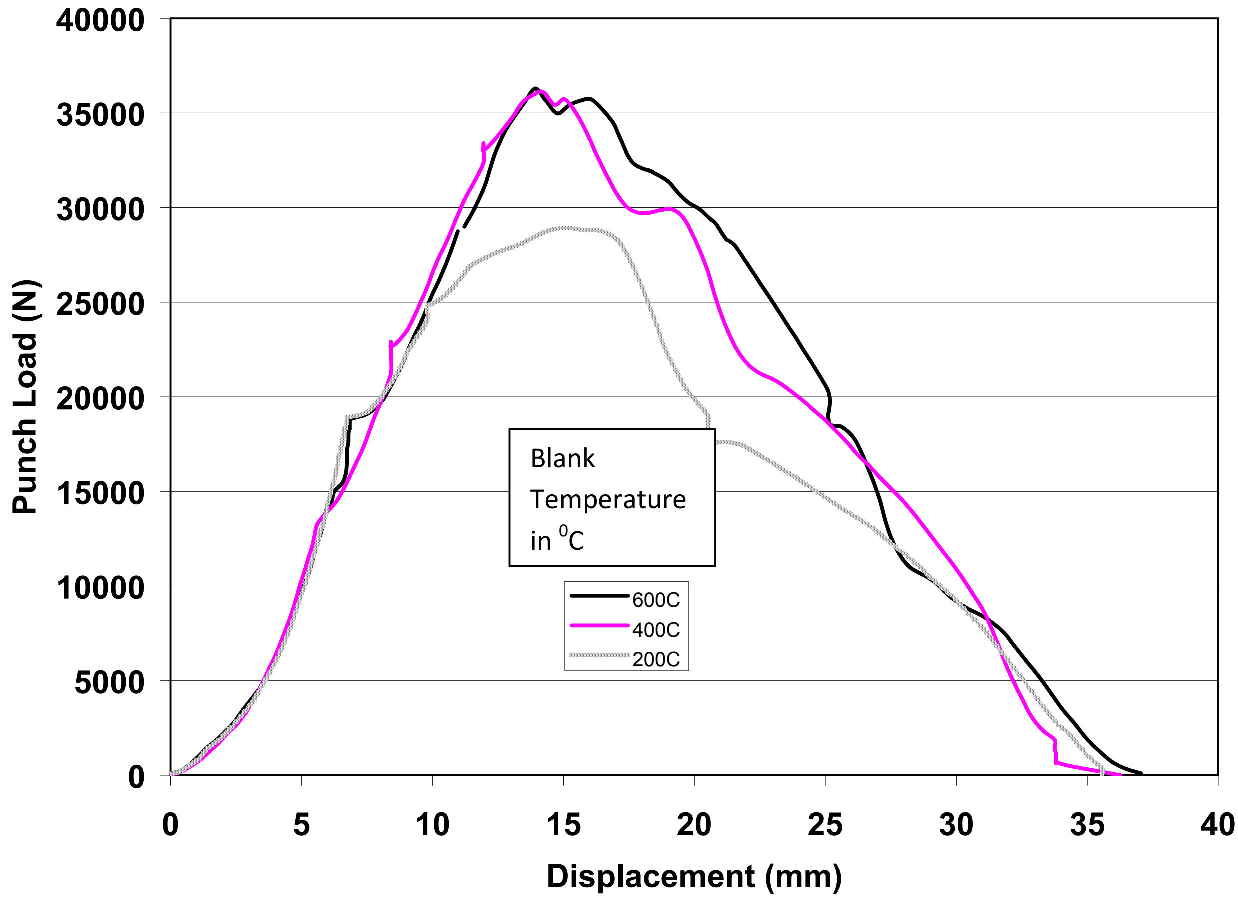

Fig. 9.11 Punch load Vs displacement graph from the data acquisition system at different blank temperatures with 60 mm blank diameters and 10% reduction in thickness

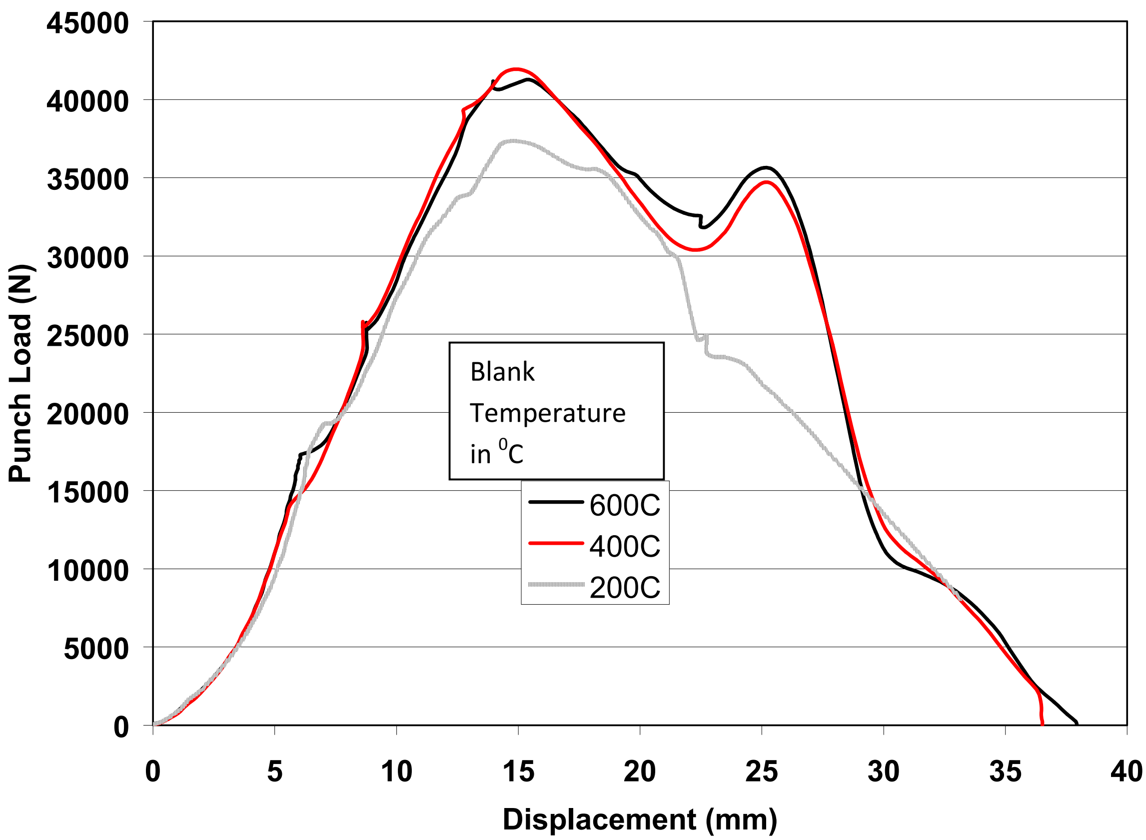

Fig. 9.12 Punch load Vs displacement graph from the data acquisition system at different blank temperatures with 62 mm blank diameters and 10% reduction in thickness

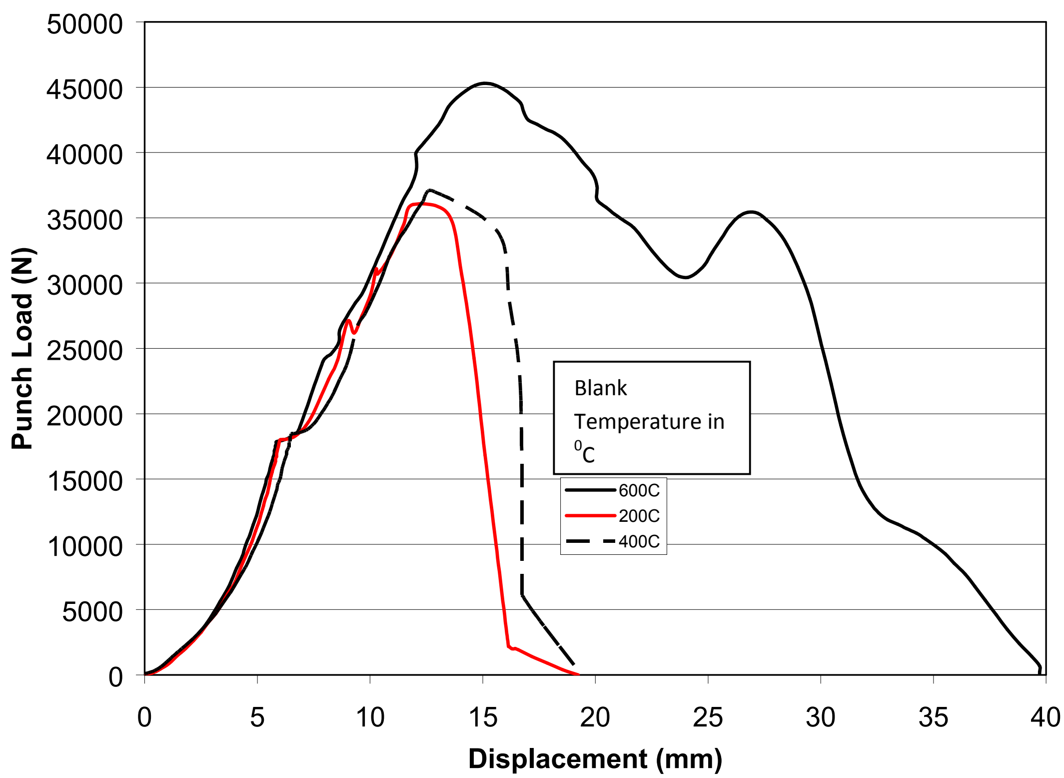

Fig. 9.13 Punch load Vs displacement graph from the data acquisition system at different blank temperatures with 65 mm blank diameters and 10% reduction in thickness

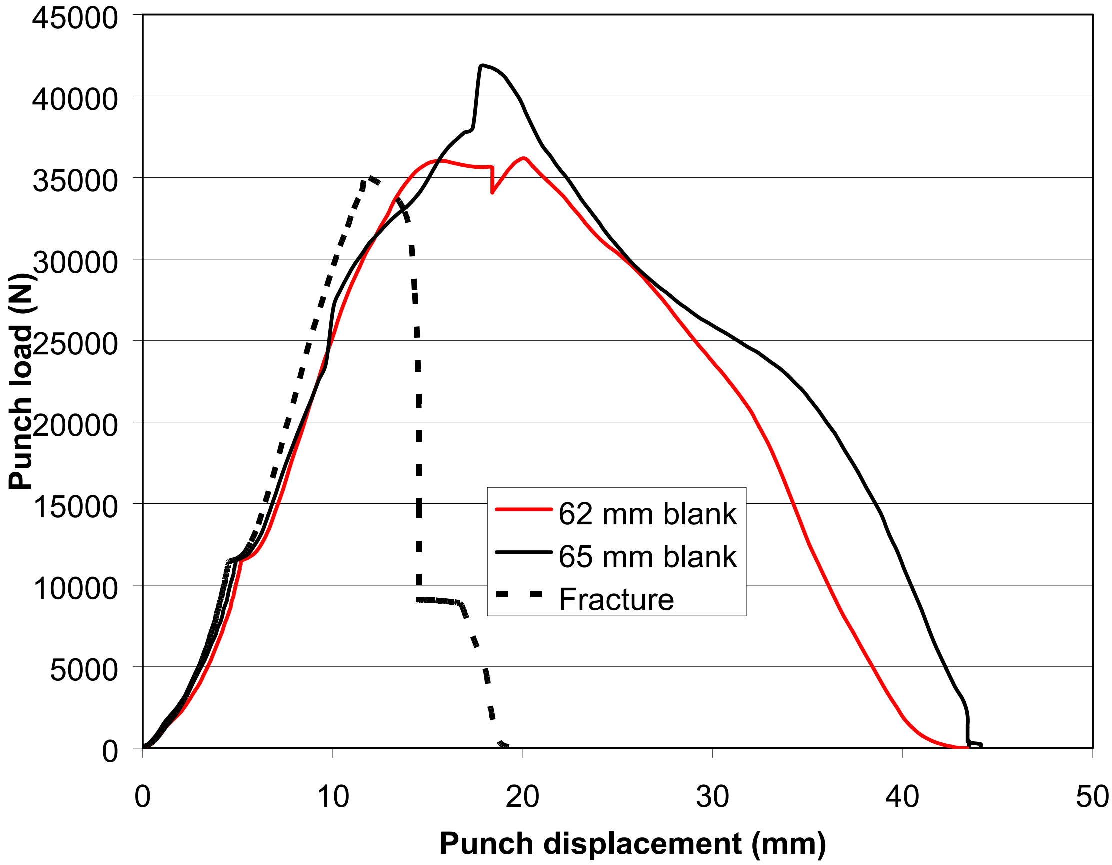

Fig. 9.14 Punch load Vs displacement graph from the data acquisition system at different blank diameters 25% reduction in thickness and 400^0C blank temperature

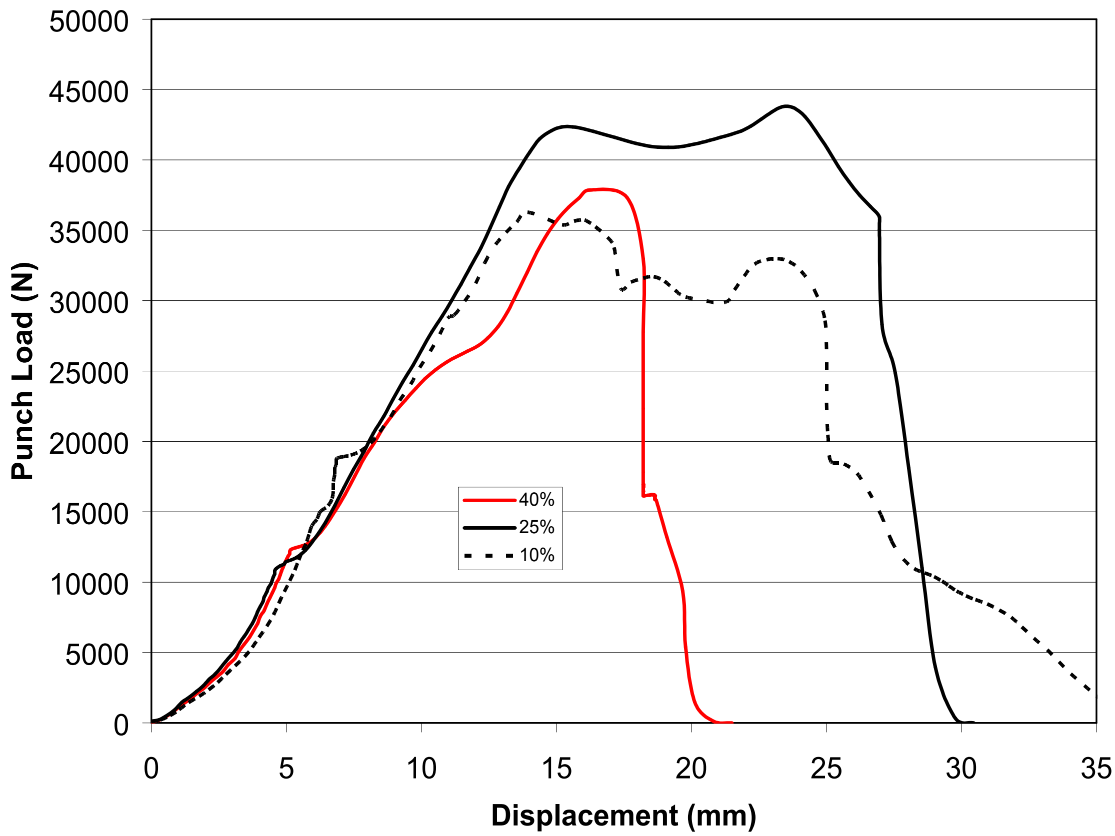

Fig. 9.15 Punch load Vs displacement graph from the data acquisition system at different %age reduction in sheet thickness at 600^{0}C blank temperature and 60 mm blank diameter

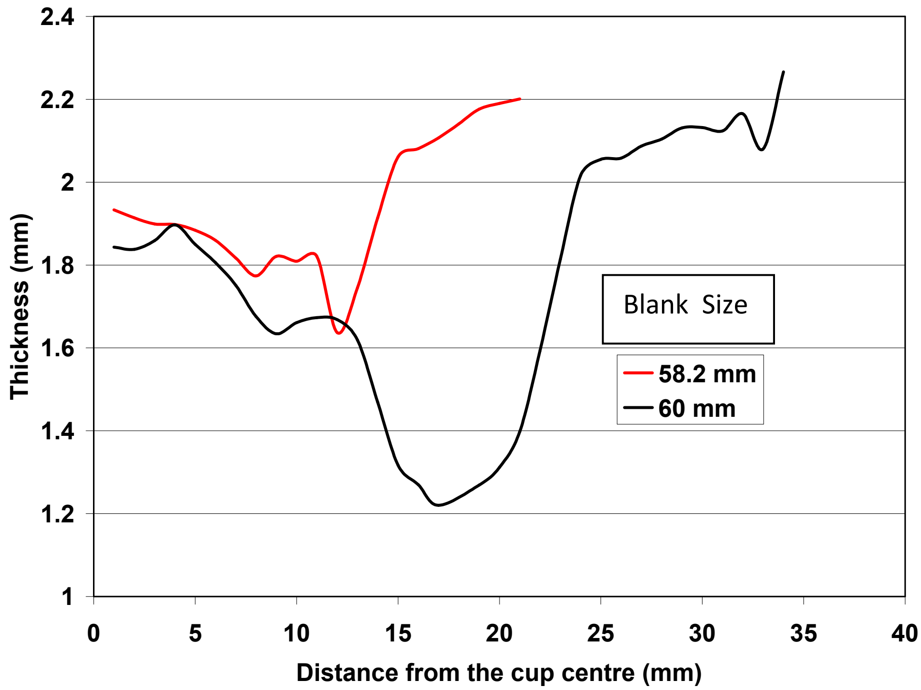

Fig. 9.16 Thickness of cup Vs distance from the cup centre for different initial blank diameter for 40%

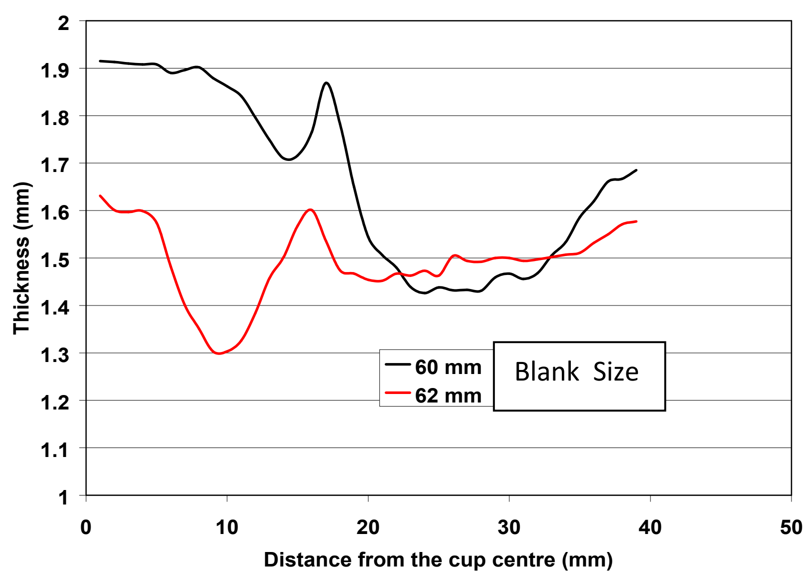

Fig. 9.17 Thickness of cup Vs distance from the cup centre for different initial blank diameter for 25% reduction and at 200^{0}C temperature.

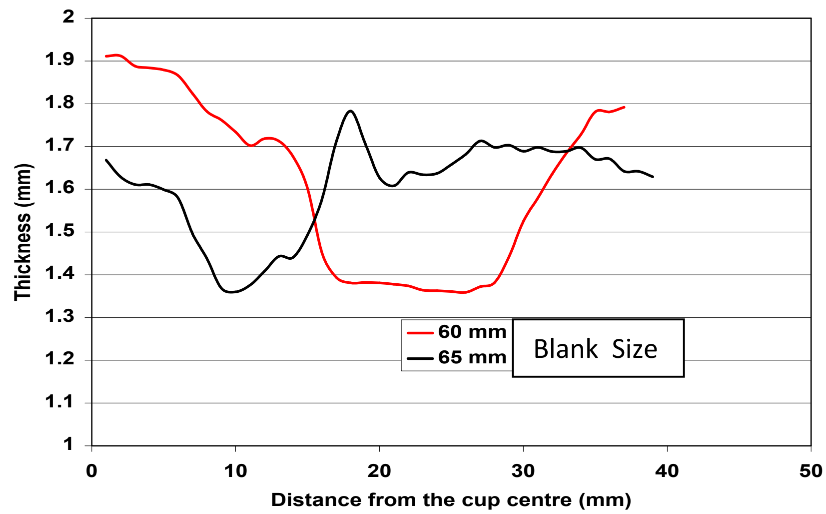

Fig. 9.18 Thickness of cup Vs distance from the cup centre for different initial blank diameter for 25% reduction and at 400^{0}C

As it is observed in fig 9.16 that by increasing the blank diameter extent of necking increases at the punch corner radius this is primarily due to max force appearing in the material in this region and also stress concentration lines are converging. Since these curves are partially drawn in the cup wall thickness keep on increasing in the drawing curve.

Fig. 9.17 and 9.18 show the variation in thickness of drawn curve with 25% reduction given to the material at 200^{o}C and 400^{o}C. It can be observed from this fig. that initially there is decline in the thickness of the curve from original 2 mm sheet thickness. This is because the clearance between punch and die is less than 2mm. beyond punch corner radius thickness in the drawn cup appears to be uniform which little equal to the clearance between the punch and die (subjected to elastic recovery). When the diameter of the blank increases beyond a limiting value (65mm), due to excessive necking fracture will appear in the drawn curve.

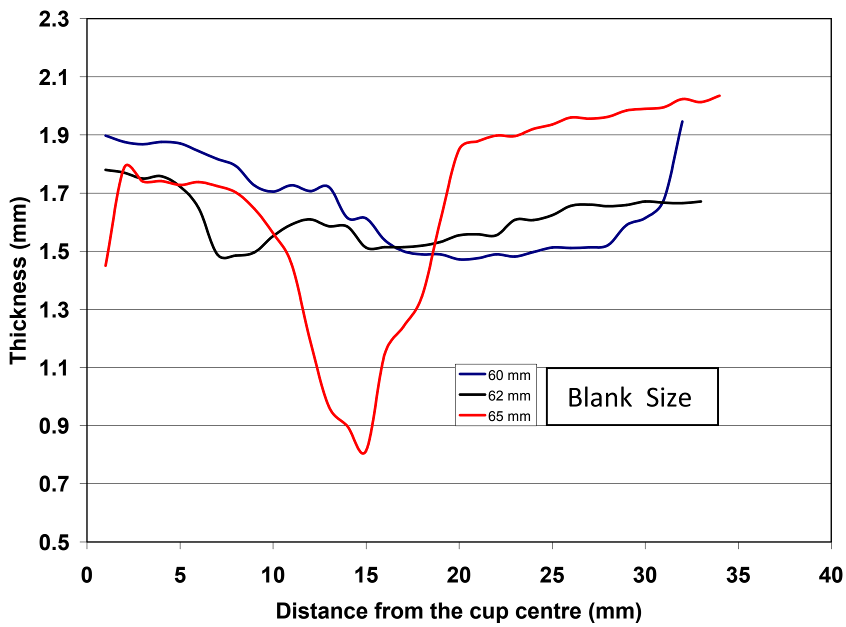

Fig. 9.19 Thickness of cup Vs distance from the cup centre for different initial blank diameter for 25% reduction and at 600^0C temperature.

It can be observed in the fig. 9.19 to 9.27 that by increasing the blank diameter at particular temperature the extent of necking increases primarily due to increase in load required to draw the material. Also thickness in the wall region appears to be more uniform when the blank diameter increases. When the temperature of the blank increases from 200°C to 400°C, thickness appears to be less at 400°C, this is because material becoming stronger at 400°C due to appearance of blue brittle phenomena. By increasing the temperature further, thickness of the drawn cup specially in the punch corner region improves because lesser stresses are required to draw the material. With 10% reduction the process is more or less deep drawing with ironing so similar characteristic can be observed in 9.24. By increasing the % reduction, thickness appears to be more uniform in the drawn cup due to excessive plastic deformation in the clearance. In fig 9.27 it should be noted that with 40% reduction it is a partially drawn cup.

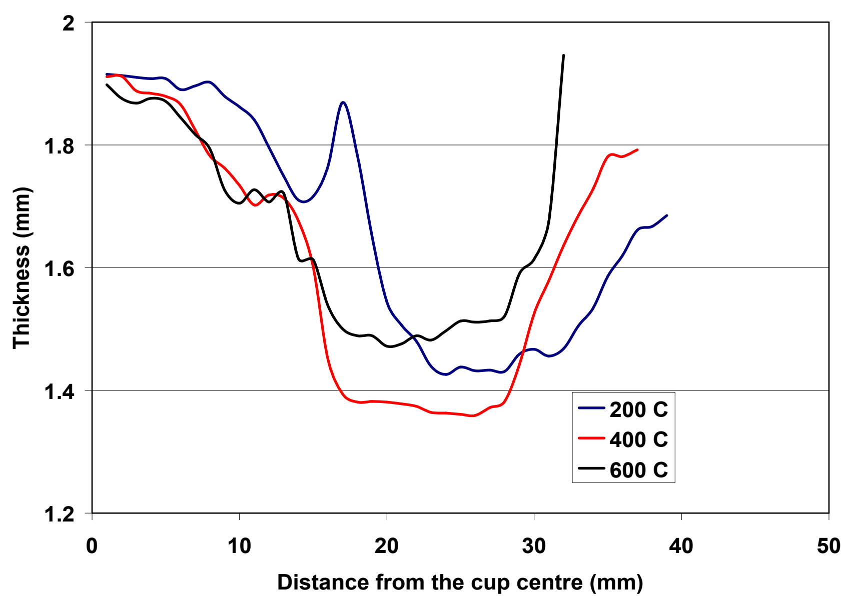

Fig. 9.20 Thickness of cup Vs distance from the cup centre for different initial blank temperatures for 25% reduction and for 60 mm blank

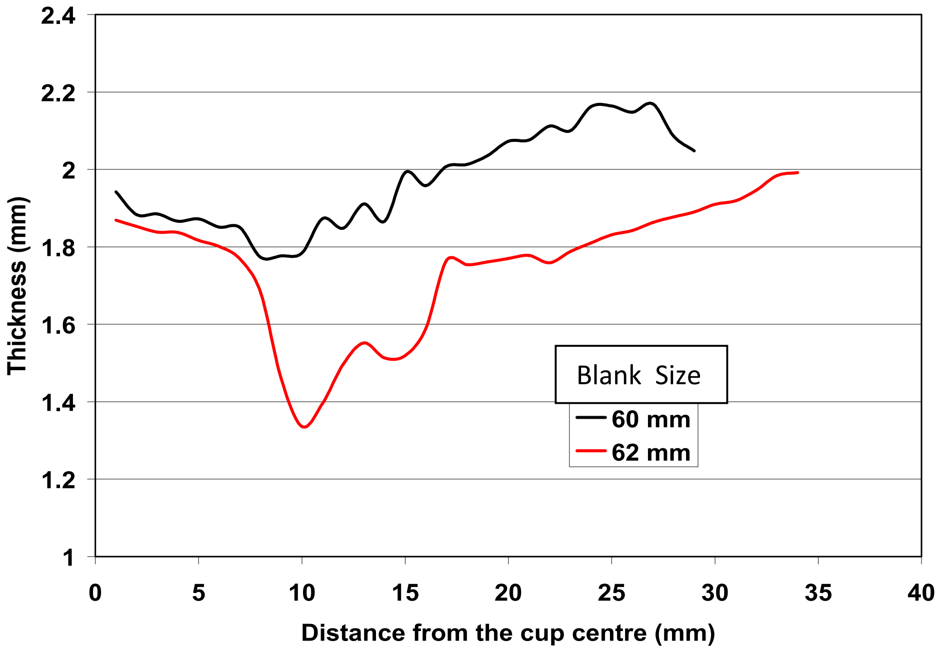

Fig. 9.21 Thickness of cup Vs distance from the cup centre for different initial blank diameter for 10% reduction and at 200°C temperature.

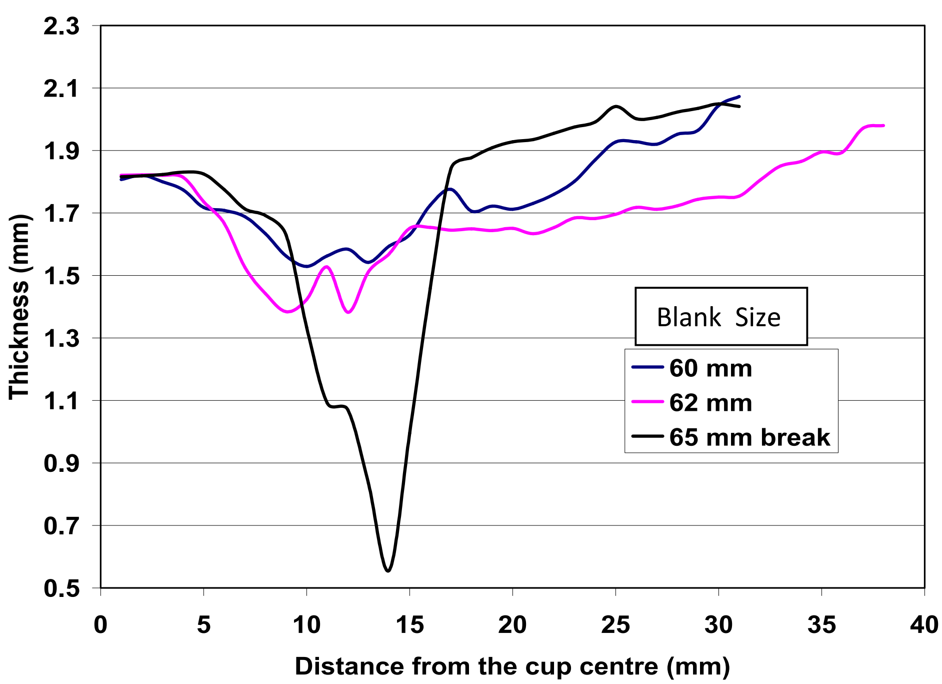

Fig. 9.22 Thickness of cup Vs distance from the cup centre for different initial blank diameter for 10% reduction and at 400°C temperature.

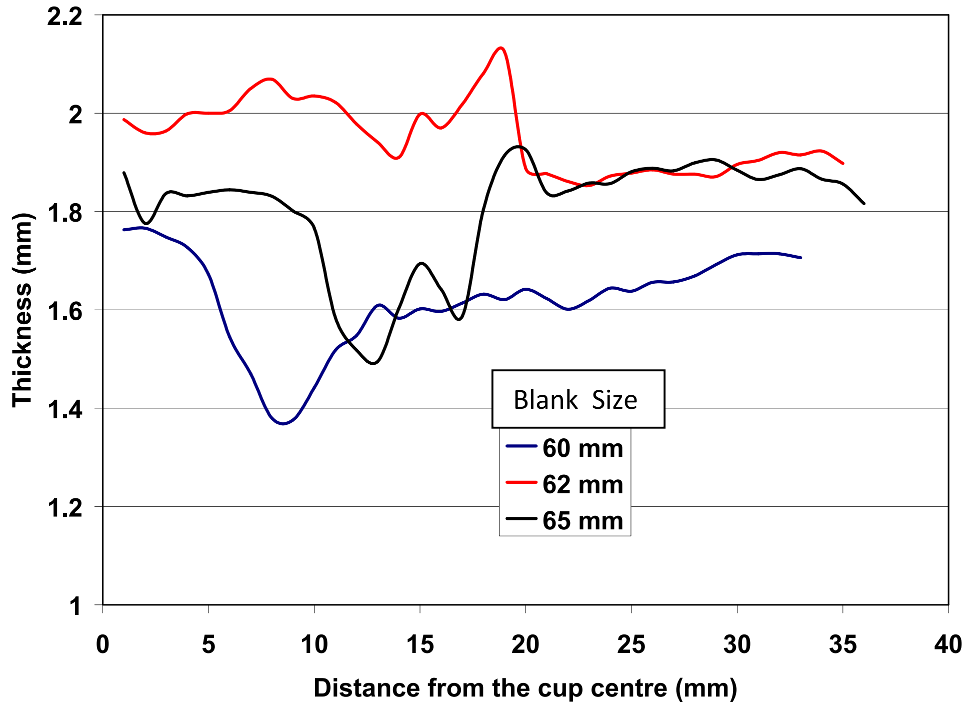

Fig. 9.23 Thickness of cup Vs distance from the cup centre for different initial blank diameter for 10% reduction and at 600^{0}C temperature.

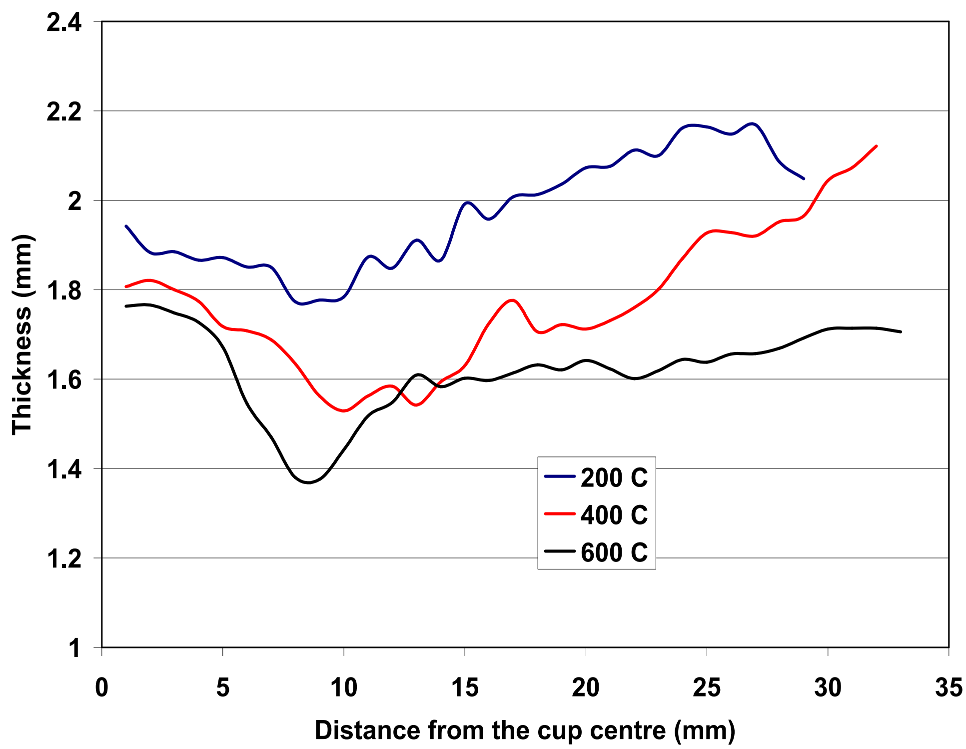

Fig. 9.24 Thickness of cup Vs distance from the cup centre for different initial blank temperatures for 10% reduction and for 60 mm blank diameter.

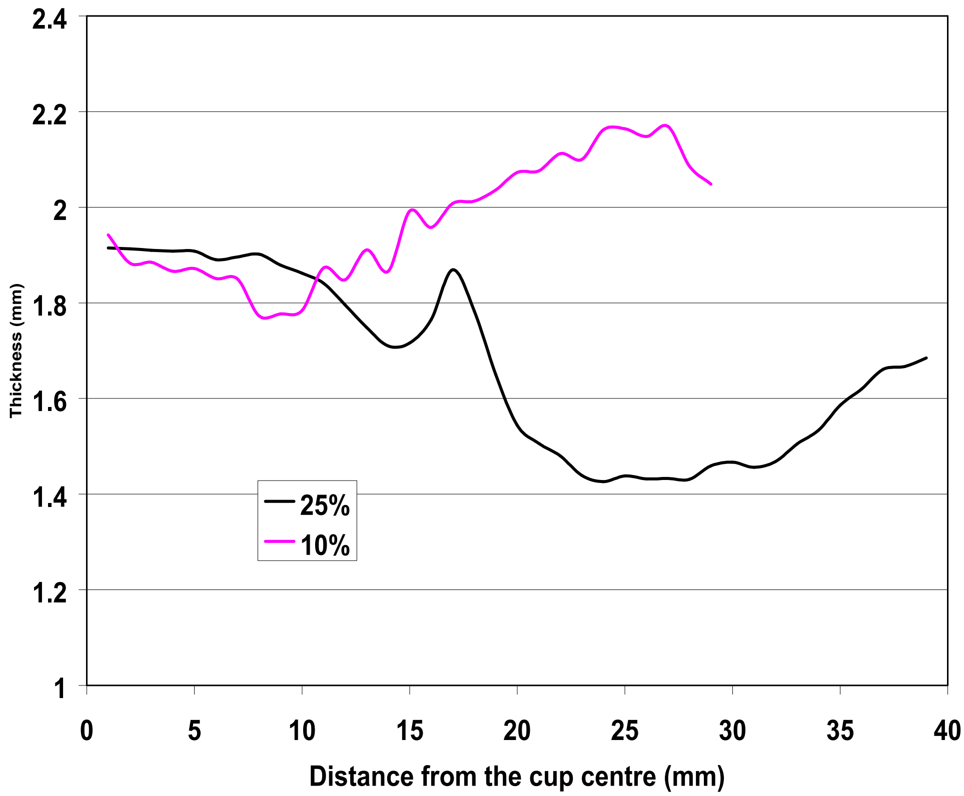

Fig. 9.25 Thickness of cup Vs distance from the cup centre for different %age of deformation for 60 mm initial blank diameter and at 200^{0}C.

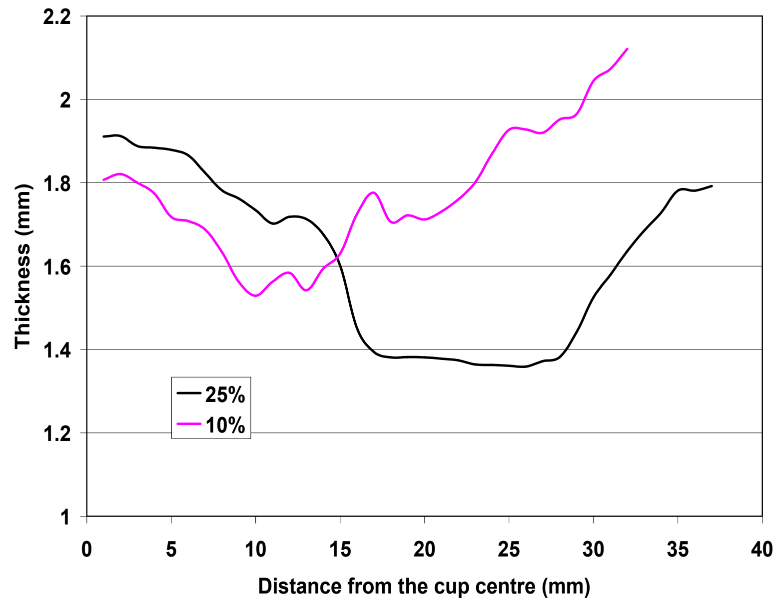

Fig. 9.26 Thickness of cup Vs distance from the cup centre for different %age of deformation for 60 mm initial blank diameter and at 400^{0}C.

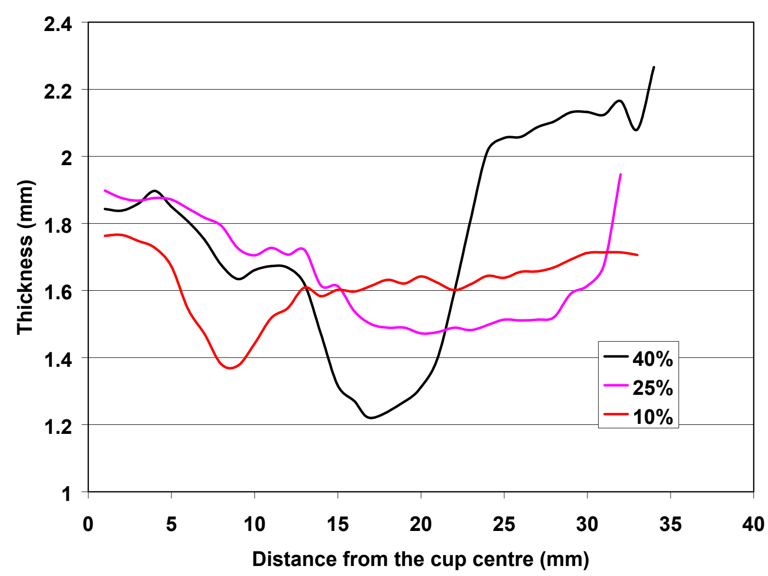

Fig. 9.27 Thickness of cup Vs distance from the cup centre for different %age of deformation for 60 mm initial blank diameter and at 600^{0}C.