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Punch Life Improvement by FEM Simulation

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Summary:
Piercing punch of a tripod piercing operation, which had very low punch life, was redesigned with the help of FEM analysis and simulation of the piercing process. Significant improvement was achieved by the stress analysis of the punch. DEFORM (© Scientific Forming Technology Corporation) was used as a virtual shop floor, for the purpose of analysis. The FEM analysis was carried out at ProSIM, and the initial design and proving of the design was carried out at Super Auto Forge. Super Auto forge has now made the FEM based analysis a part of the upstream design process to ensure quality.

Cold piercing of the tripod was chosen for high productivity at Super Auto Forge Ltd. A forged tripod is shown in figure 1.The punch life was very low with typical failures occurring at the tip of the punch. Figure 2 shows photographs of the some of the punches. Punches were made of HSS and heat treated to 60-62 -HRC. After preliminary inspection of the fractured punches, the failure was attributed to a combination of plastic deformation of the tip, low cycle fatigue, crack initiation due to surface scratches formed during punch withdrawal,punch-wear and possible unfavorable stress states. (tensile stress state in the punch).

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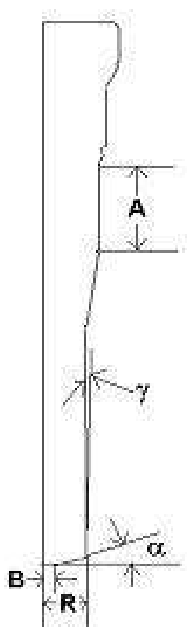
Figure 1.Forged Tripod

Figure 2.Punches

A FEM analysis based simulation of the piercing operation and punch stress and punch (elastic) deflection analysis was carried out. Multiple number of design options were tested using computer as a virtual shop floor for try out of the design. Results of four typical design cases are described in this article to demonstrate the utility of the FEM analysis.(The best / optimized result is not shown in the article.)Figure 3.Shows the geometric parameters which are varied in different cases of punch design.Figure 4. shows the simulation of the piercing in progress in an intermediate stage.



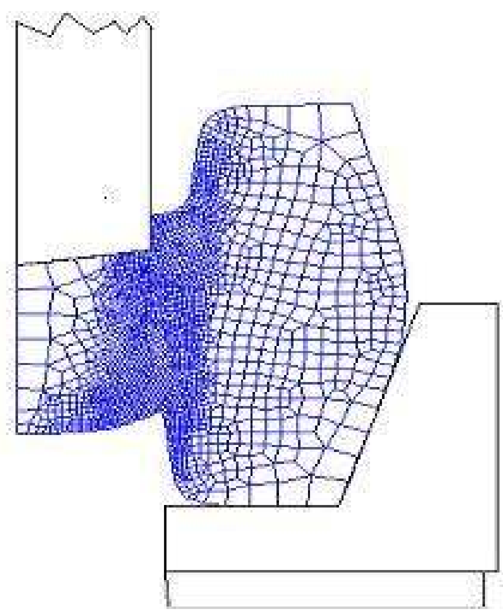


Figure3.PunchGeometry(Parameters)

Figure4.FEM model showing the . Intermediate Stage of piercing operation

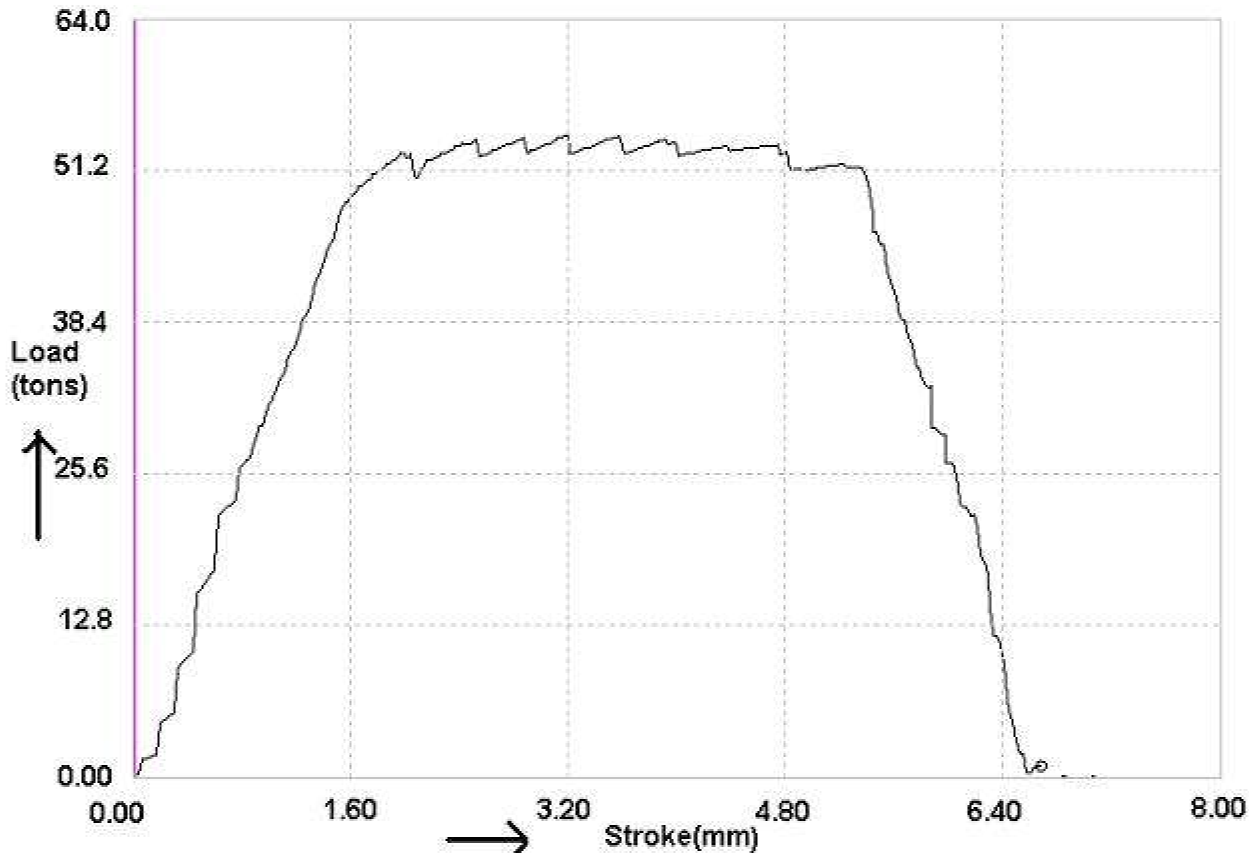


Figure 5.Load/stroke curve

Figure 5 shows the punch load-stroke characteristic during piercing. In FEM analysis of the punch stresses, the load exerted on the punch will be extrapolated and the resultant stresses and deflections in the punch is evaluated.

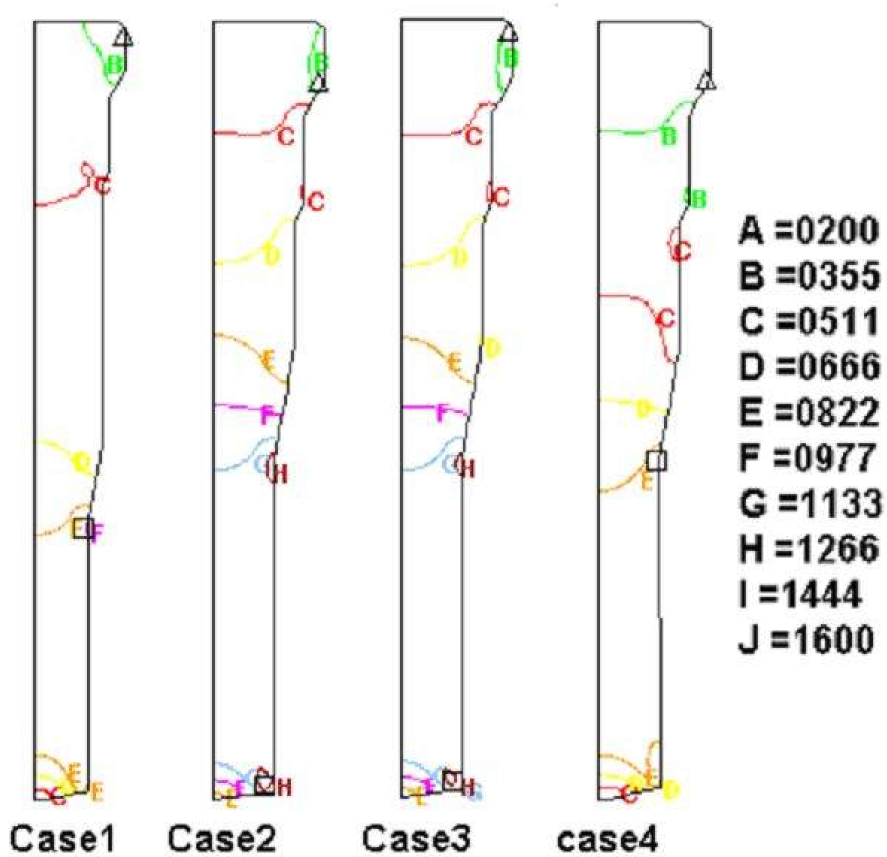
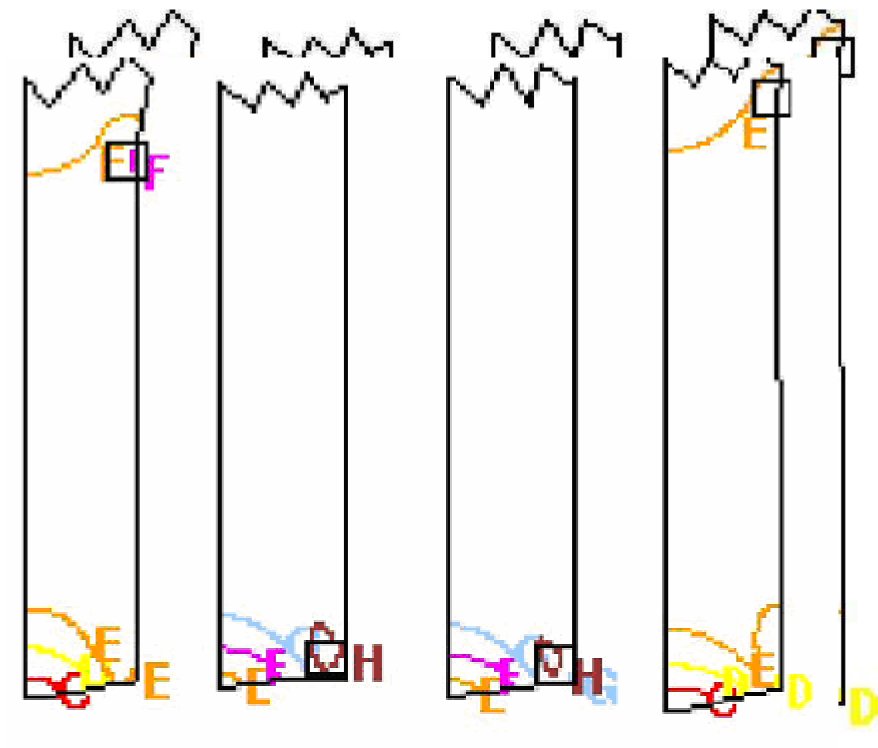


Figure 6.Effective stress in the punch for different designs.

Figure 6 shows the effective stresses (or Von Mises Stress) for 4 different cases of punch design. Effective stress exceeding the yield strength will cause *plastic deformation and will affect the low cycle fatigue.* From the figures it is observed that case-1 has very high effective stress at the tip and case-4 has the lowest stress level.



Case1 Case2 Case3 Case4

Figure 7.Zoomed views(punch tips) of Effective stress in punch for different Designs.

In the Figures 7, Symbol □ shows the location of maximum stress and symbol △ shows the location of minimum stress.In the case 4 it is seen that the location of maximum stressis shifted away from the tip and the stress level at the tip has been brought down from 1420 Mpa to 500 Mpa. Figure 7 shows the exploded/zoomed view of the stress profile in the tip of the punch.

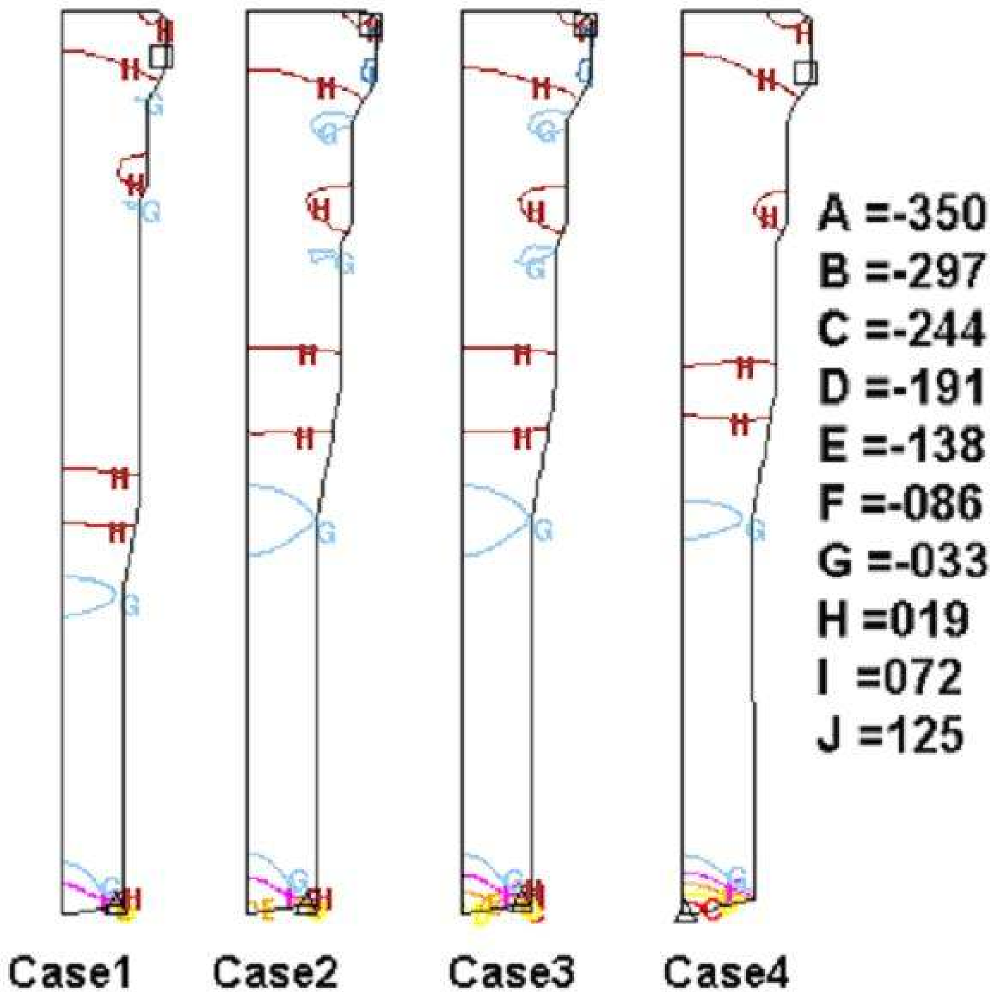


Figure 8.Maximum principle stress in the punch for different Designs.

Figure 8 shows the maximum principal stress, which causes fracture for different punch designs. Here too the tensile stress component of the stress is seen to be lowest in the case-4.

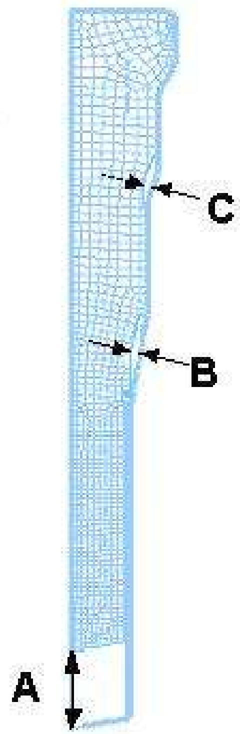
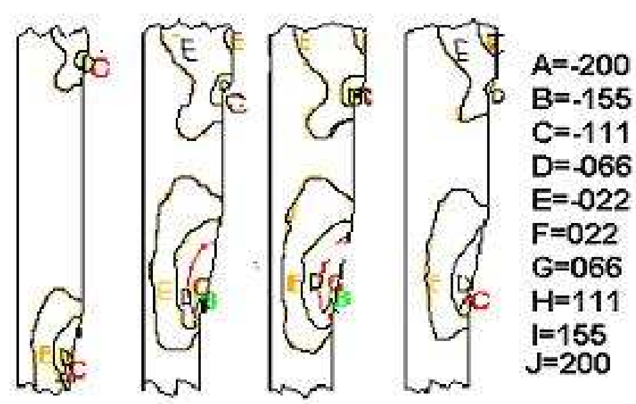


Figure 9.Deflection of punch(Magnification is 25 times)

Figure 9 shows the elastic deflections in the punch tip. It is seen that in case-4 the punch deflections are reduced by 32 % compared to case-1.
Figure 10.shows the shear stress, which is due to bending of punch caused by deflections at B&C as shown in figure 9. Here too the compression stress component of the stress is seen to be lowest in the case-4 @perticuler locations as shown in figure 10.



Case1 Case2 Case3 Case4

Figure 10.Shear stress in the punch for different designs.(zoomed view)

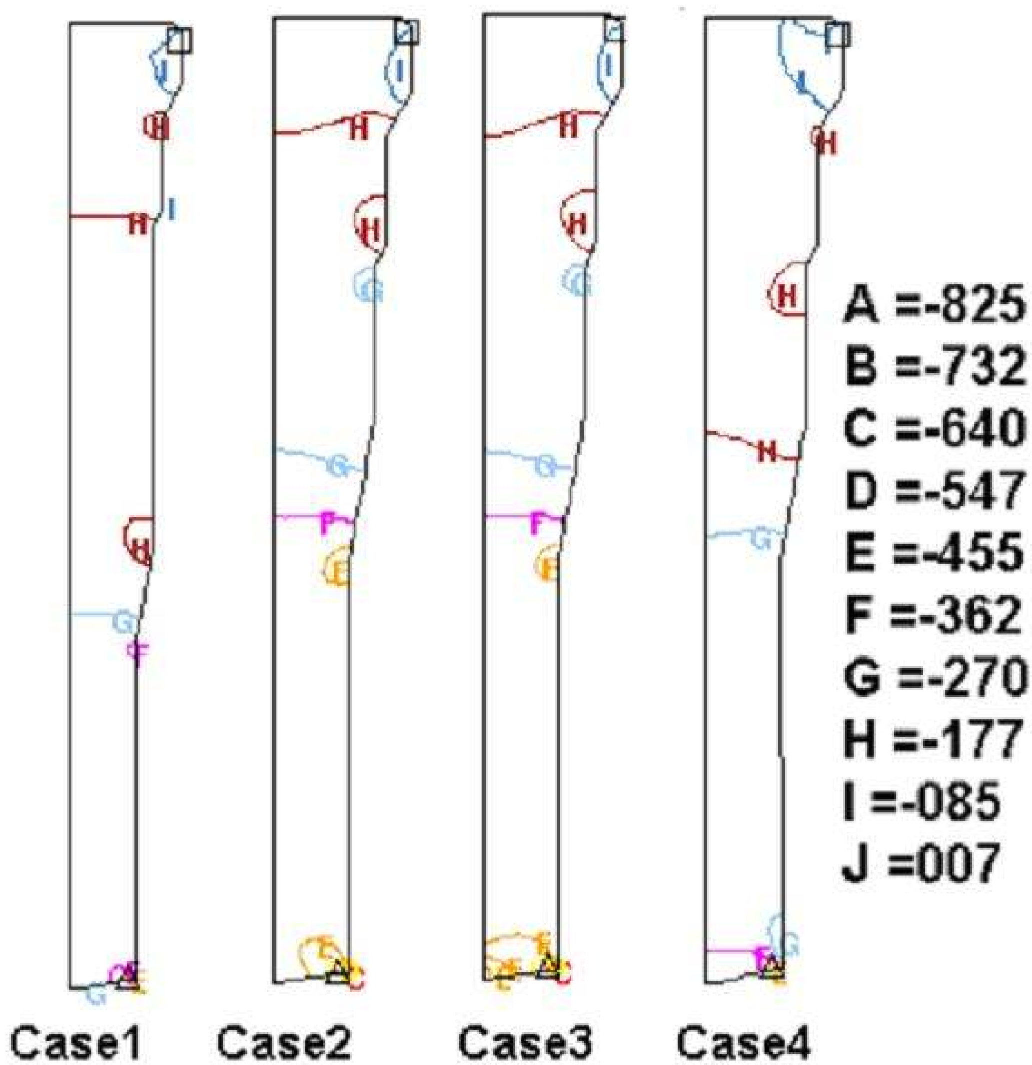


Figure 11.Mean stress in the punch for Different Design

Figure 11 shows the mean stress distribution in the punch for various cases. It is known that mean stress (or hydrostatic stress) determines the wear of the dies. Mean stress seems to be higher in case-4, a case other wise best suited

From the tendency for plastic deformation,low cycle fatigue and the punch design as in case-4 is found to be better alternative.
By the case-4 punch showed improvement of punch life by 350%.Wear marks are observed in the punch as seen in Figure 11.

. Table-I showsThe results summarized

TABLE-I

	CASE1		CASE2		CASE3		CASE4	
STRESSES(Mpa)	MAX	MINI	MAX	MINI	MAX	MINI	MAX	MINI
EFFECTIVE(Fig no.-5)	1003	218	1425	239	1401	221	941	160
MEAN (Fig no.-9)	-31	-533	-7.78	-748	4.44	-750	-13.31	-501
MAX.PRINCIPLE(Fig-7)	82	-203	98	-258	105	-268	64	-289
DEFLECTION(mm)	MAX	MINI	MAX	MINI	MAX	MINI	MAX	MINI
Location A (Fig no.-8)	0.3708	------	0.4191	------	0.4241	------	0.2923	------
Location B (Fig no.-8)	0.028	------	0.0224	------	0.0208	------	0.0148	------
Location C (Fig no.-8)	0.016	------	0.0224	------	0.022	------	0.0148	------

Conclusions:
By using the FEM simulation of piercing and subsequent punch stress analysis, the punch life was improved by more than 350%. In the piercing punch studied the failure was predonimently due to punch deflection,punch wear,&low cycle fatigue.To address each of this failure mode different strategy have been adopted.FEM based simulation of the piercing operation is an useful tool to validate and prove the design in the upstream of the design process using the simulation and modeling, The lead time can be greatly reduced to arrive at the best possible process and tooling design.