Design and analysis of progressive tool for an automobile component

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Abstract. Dies are used in forming industries from several years, especially for sheet metal. Progressive dies are forming tool which involve in performing more than two different operations at working stations. The finished product is obtained from the raw material by forming from first station to last station. To design and develop various components in metal forming is very complicated task. Current study is focused on design and develop a progressive die to manufacture tail gate striker used in head lamp assembly, which previously manufactured using different dies. Progressive die uses low cost standardise tools for improvement in production. Progressive die leads to various uncertainties, which results in manufacturing loss of component. Based on the experience of the designer, it is require to identify the risk and resolve the same at the time of design. Use of CAE in designing and developing the progressive die for automobile component is discussed in brief with analysis. Use of progressive die results in maximum usage of raw material to manufacture the desired component. With use of progressive die, overall rate of production increases with less labour cost.

Key words- Design complexity, progressive die, computer aided design and analysis, precision tooling, increased production rate etc.

1. Introduction
Press stampings are used as a prime preference for mass production of numerous mechanical components. In tool engineering, die design is a very significant task as it requires expertise to get accurate shape and dimensions. Dies are used in various forming and stamping operations to obtain the desired shape of component. Tail gate striker, used in assembly of head light of an automobile is required to manufacture using progressive die. As the requirement of the component significantly increases by the customer, it is required to manufacture the component within less time. Metal forming operations are very important in mass production. Skill and experience of the die designer is more important aspect in design and development of die [1]. Usage of progressive dies in stamping operation is a vital and advanced technology for improvement in productivity. Parts with complex shapes can be formed or stamped by using progressive dies [2]. Design of progressive dies requires high level of engineering and accuracy for getting exact layout of vast number of stamping stations in a restricted and narrow shape [3]. Die is required to design for minimising the overall lead time of operation and cost along with improvement in accuracy. So it indicates the standard design procedure and analysis of progressive die for number of operations required to obtain the final desired shape.

2. Literature review
In a knowledge-based expert system (KBES) issues are more important related to the modelling and analysis of the progressive stamping process. Various knowledge-based method for progressive stamping die design are discussed. Various techniques for representation of punch shape, die component and work piece shape synthesis are presented to develop a KBES system [4]. Standardisation of the conventional progressive die in tooling and press machine technology is one of the significant factor in
current metal forming process [1]. Progressive tool is a productive tool in mass production to improve the rate of production. It requires more planning as well as skill to design and fabricate the tool as, it consist of standard elements and thumb rule. Special jigs and fixtures requires to design for manufacturing the press tool as special orientation of all the components is necessary [5]. Multi-step unfolding method (MSUM) is used to predict formability of complex part in progressive die. In line with stamping process inverse approach is developed to study intermediate shape by unfolding the component. Inverse sequence is used to produce intermediate shape and final shape [6]. Progressive draw dies are used to manufacture automobile bulb shield. Progressive dies consist of multiple stations, so it requires more precise design of the die component as final desired shape of the component is obtained after performing all the operations accurately [7]. Finite element method is used to find various causes of defects observed in forming method using progressive die. New progressive process design is suggested to modify intermediate stage of forming [8]. Practical system using CAE for blanking irregular shape component is discussed and used to solve practical problems [3].

3. Problem Statement
Initially, the component was manufactured from single station dies for different operations. The overall rate of production was less compared with the requirement of the component, due to generation of defects and increase in overall lead time. So it is required to develop a progressive die for the same component with reduction in production time as well as cost without affecting the accuracy.

4. Objectives
- To reduce production time along with cost.
- To achieve maximum accuracy.
- To reduce the labour cost.
- To improve quality of the product.

5. Design of progressive die
The material used for die is HcHcr [9].
The required data is collected to design the progressive tool and various steps are included as discussed below. Data available as from the product and material of product is given below,

| Material of product   | Mild steel |
|-----------------------|------------|
| Thickness of material | 1 mm       |
| Shear Strength        | 400 N/mm²  |
| Length                | 76 mm      |
| Width                 | 45 mm      |
| Pierce diameter d₁    | 21 mm      |
| Pierce diameter d₂    | 7 mm       |
| Fillet radius R₁      | 20 mm      |
| Fillet radius R₂      | 3 mm       |

Piercing and blanking operations are performed on the component to obtain the desired shape. Material HcHcr is selected for die as it is hardened material. By calculations various parameters found as given below,

5.1 Calculation of Various Parameters
a  Punch and die size for piercing holes:
   Die size, Ø 7.12 mm and Ø 21.12 mm
b  Punch and die size for complete blanking:
   Size of die would be same as size of the original blank.
c  Cutting Force:   = 15.06 Ton
d  Actual Press Tonnage:   = 19.578 ≈ 20 ton
e  Die Plate Thickness:   = 22 mm ≈ 25 mm (25 mm D2 block)
f  Top Plate:   = 44 mm ≈ 45 mm
   For deflection, (δ)   = 0.2829 mm
g  Bottom Plate:   = 44 mm ≈ 45 mm
For deflection, (δ) = 0.03836 mm

Guide Pillar Calculations:
Shut Height = 160 mm
Press tonnage = 20 tons

As per requirements 4 pillars will be used here,
For single pillar force tonnage = 20/4 = 5 ton/per pillar
Here the load that will act on pillar is the crippling stress for M.S.
σ_cr = 250 MPa

Crippling load = 69.39 N/mm² which is safe for M.S.

Strip Layout:
Area of Product = 3000 mm²
Area of Sheet = 102.5×10³ mm²
Total length of sheet = 1250 mm
Total length of single product = 51 mm
Number of blank = 1250/51 = 24.5 Nos.
Thus number of blank per sheet = 24
Total area of single product = 3000 mm²
Now for 24 product = 3000 × 24 = 72000 mm²
Utilisation of sheet = (72000/102.5×10³) × 100 = 70.24%

Punch Holder Plate and stripper plate: = 11 mm
Thrust Plate: = 8 to 9 mm

6. Modelling
For modelling AutoCad 2014 and NX software is used. CAD model of component is shown in Figure 1 and solid model of progressive die is shown in Figure 2,
Assembly view of progressive die is shown in Figure 3,

![Figure 3. CAD model of progressive die assembly](image)

7. Analysis
Static and modal analysis are done using progressive die assembly. The progressive die assembly is meshed with first order 3D Hexa-element and Second order Tetra elements in Ansys Workbench as shown in Figure 4. SOLID185 is used for 3-D modelling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element is having plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities.

![Figure 4. Meshed model of progressive die assembly](image)
7.1 Modal Analysis

The vibration characteristics of the component like mode shape, are determined by model analysis as a part of dynamic analysis [10]. Vibration mode at every step and natural frequency are very significant factors when structure subjected to the dynamic load [11]. Total 5 frequencies are considered for analysis. Figure 5 shows the frequency wise modal analysis of the die.

Figure 5. Modal analysis of component
7.2 Static Structural Analysis

Static structural analysis is used to find out the stresses, strains, induces forces and displacement in the component. When the system structure subjected various loads, developed stresses and strains are calculated using structural analysis [12]. Figure 6 shows the various Von Misses stresses developed in various component of assembly and Figure 7 shows the total displacement observed in the assembly.

(a) Von Misses Stresses generated on die

(b) Von Misses Stresses on stripper

(c) Von Misses Stresses on top plate

(d) Von Misses Stresses on punch and holder plate

(e) Von Misses Stresses on bottom plate

(f) Von Misses Stresses on guide pillars

Figure 6 Von Misses Stresses on various components of progressive die
8. Observations and Results

From the above modal analysis it is observed that first natural frequency on the progressive die assembly is 12 Hz. The operating frequencies or external excitation frequencies should not coincide with the said above natural frequencies in order to avoid resonances. The observed frequencies for all modes are appended in Table 1.

Table 1. Observations from modal analysis.

| Mode | Frequency |
|------|-----------|
| 1    | 12.38     |
| 2    | 119.6     |
| 3    | 143.91    |
| 4    | 404.59    |
| 5    | 497.07    |

From the static structural analysis using die and punch as the parameter obtained Von Misses stresses and yield stresses are appended in the Table 2. It is observed that maximum Von Misses stresses are well below the yield stress.

Table 2. Observations from static structural analysis.

| SR.NO. | PARAMETERS | VON MISSES STRESS (MPa) | YIELD STRESS (MPa) |
|--------|------------|-------------------------|--------------------|
| 1      | DIE        | 162                     | 827                |
| 2      |            | 107                     | 370                |
| 3      |            | 55                      | 370                |
| 4      | PUNCH      | 140                     | 827                |
| 5      |            | 13                      | 370                |
| 6      |            | 14                      | 370                |

Hence the progressive die assembly components are safer for the provided boundary conditions.

9. Conclusion

Progressive die is designed for manufacturing of the automobile component which is required to assemble the headlight assembly in an automobile. Analytically calculated dimensions and the results obtained from the analysis are well with the limit. The results obtained from the frequencies, stress and strain values are in tolerable range. Overall time required for the manufacturing of the component with separate dies will be more compared to progressive die. By using progressive die the rate of production
will increases and manufacturing as well as labour cost decreases. Appreciation based on results obtained for concern experimentation is confirmed by the industry for validation.

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