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Significance Of Thermal Barrier Coating In Din 2714

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ABSTRACT

A significant issue with the hot forging process is the intense stress and high temperatures involved, which can cause the die to fail. This research examines how to prevent die failure by applying a glass coating to the die's surface. The focus is on a die made of Din 2714, a type of German standard steel, during the hot forging of waspaloy. Forging was attempted using the traditional method, which is challenging due to the heat escaping from the die's surface and the limited temperature range of waspaloy. To address this, a thermal barrier coating, Delta Glaze FB412, was applied to the die's surface. Thermal analysis was performed using Ansys software, revealing that the coating effectively reduced heat loss from the die's surface. To confirm these findings, two halves of the die's surface were coated with Delta Glaze FB412. After the die underwent adequate heat treatment, it was installed on a forging machine, and the forging process was conducted according to the product's production procedures. Upon completion of the forging, it was observed that the product was defect-free. Further examination after the process showed no signs of die failure or plastic deformation.

KEYWORDS:
Plastic Deformation, Hot forging Process, Waspaloy, Din 2714, Delta Glaze FB-412

INTRODUCTION

The research was designed to inquest failure during the production of Waspaloy, a trademarked nickel-based super alloy, while it was being hot forged at 1010°C, because it experienced plastic deformation on the die. Waspaloy, known for its use in high-temperature environments and gas turbines, maintains its strength and resistance to corrosion at these high temperatures, with forging temperatures ranging from 1010°C to 1080°C. In the forging process of Waspaloy alloy the failure of the die due to plastic deformation was anticipated. The die was constructed from hot-worked steel of DIN 2714. Forging Waspaloy using traditional methods is challenging due to its high strength at forging temperatures. The significant difference in temperature between the die and the workpiece leads to a die cooling effect. This study was carried out to find an effective method for reducing the temperature difference in industrial settings. Research on the reasons for deformation and the impacts of applying a thermal barrier coating with delta glaze FB 412 to the die's surface have been carried out. This involved conducting thermal and stress analyses using
Ansys software, which were then validated through real forging operations.

METHODOLOGY

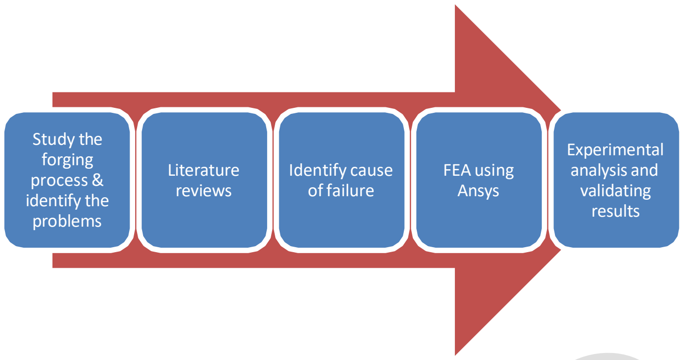

Fig. 1: Methodology

THERMAL SOFTENING & PLASTIC DEFORMATION OF DIES

Die life is significantly influenced by various factors, including die material, die design, and forging conditions. Common failures include catastrophic fractures, wear, mechanical and thermal fatigue, and plastic deformation. Key variables in the forging process are: a) the flow behavior of the material being forged under processing conditions, b) die geometry and materials, c) friction and lubrication, d) the mechanics of deformation, including strains and stresses, e) the characteristics of the forging equipment, f) the geometry, tolerances, surface finish, and mechanical properties of the forgings, and g) the environmental impact of the process. Repeated hot forging operations increase the die temperature, which decreases the surface hardness of the die, leading to thermal softening. This softening accelerates wear and plastic deformation. The plastic deformation can be assessed by comparing the effective stress to the yield strength of the die material at the same temperature. Chanin Tavichaiyuth and Yingyot Aue-u-Lan studied the plastic deformation and abrasive wear of hot-forged axle shafts, collecting data from the hot forging process. This data included the characteristics of the screw press (such as energy, moment of inertia, and blow efficiency), initial die hardness profile, temperature measurements of the workpiece and forging die at steady-state temperature, and forging load. Heat transfer from the workpiece to the die surfaces creates thermal gradients in the workpiece, causing the surface near the die to experience less plastic deformation due to the die chilling effect. This uneven plastic flow increases stress on the die. Forging Waspaloy using conventional techniques is challenging due to its high strength at forging temperatures and the need for precise control. The forging of nickel-based alloys is further complicated by their low ductility and high resistance to deformation at elevated temperatures. These alloys exhibit high flow stress, high recrystallization temperatures, and a narrow forging temperature range of 1000-1100°C, making the process difficult. In isothermal forging operations, however, controlling forging conditions is easier, resulting in higher homogeneity of the product's microstructure and mechanical properties. The microstructure of Waspaloy can be more easily controlled in isothermal forging compared to conventional forging.

DIE CHILLING & SURFACE COATING

Heat transfer from the workpiece to the die surfaces creates thermal gradients within the workpiece. The area near the die surface undergoes less plastic deformation due to die chilling. This chilling effect can be reduced or eliminated by maintaining the die at the same temperature as the workpiece, a process known as isothermal forging. However, this is not feasible in conventional setups due to the need for a vacuum to prevent die oxidation. Another method to mitigate the die chilling effect is using thermal barrier coatings, which prevent heat loss from the die surface and thus decrease the thermal gradient. There are several ways to extend die life, including using newer and more wear-resistant die materials, optimizing die geometry to reduce wear intensity, and applying proper heat treatments, coatings, and hard facing. Surface engineering techniques have also successfully improved the wear resistance of hot forging tools. Recently, hard coatings applied through physical vapor deposition (PVD) have shown significant potential in enhancing the tribological properties of contact surfaces. Ritanjali Sethy investigated the use of glass coating (CONDAERO 228 glass coat) on titanium forging and its effects on the heat transfer coefficient and coefficient of friction. Transient heat conduction occurs during the heating and cooling of metal billets, and the heat transfer coefficient can be determined using the following equation.

$$\frac{t - t_a}{t_i - t_a} = e^{-\frac{hA_S\tau}{\rho V}}$$

Where:

t_i = initial temperature

t_a = ambient temperature T = temperature

h =heat transfer coefficient W/m^{2}K As = Surface area in m^2

τ = time in seconds C = specific heat

ρ = density V = Volume

THERMAL BARRIER COATING

Thermal barrier coatings are applied to metallic surfaces that operate at high temperatures. Current die coating technology uses a water-based suspension of ceramic particles, with sodium silicate being the most common water-based binder. These coating mixtures require careful storage, and their preparation can be labor-intensive, especially at elevated temperatures. Glass coating materials consist of glass powder, a binder, a rheological agent, and wetting and viscosity modifiers dispersed in a carrier. Commercially, glass coatings are available under the trade name Bonderite L-FG412 (Delta Glaze). It is a dispersion of a specially developed rigorously controlled Glass frit in water designed for a protective coating on forging dies and titanium and super alloy

billets. The salient features of delta glaze are: 1. Unlike other glazes it is lead free and solvent free
2. Assist to control metal flow 3. Reduce Heat loss from Surface 4. Delta glaze is available in liquid form so dip, spray or Manuel application is possible on surfaces.

Fig. 2 Delta Glaze FB412 Solution

ANALYSIS

Thermal analysis of die with coating and without coating has been done by using ANSYS. Here model of dimension 290x290x70 mm was used. The analysis of coated and uncoated models using the ANSYS software have been illustrated in the figures given below.

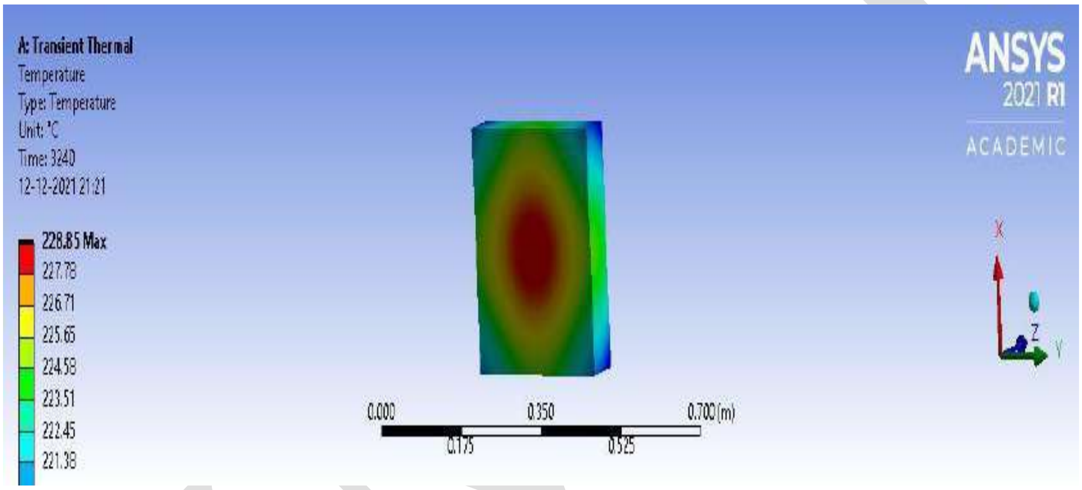

Fig. 3: Temperature Distribution of uncoated specimen

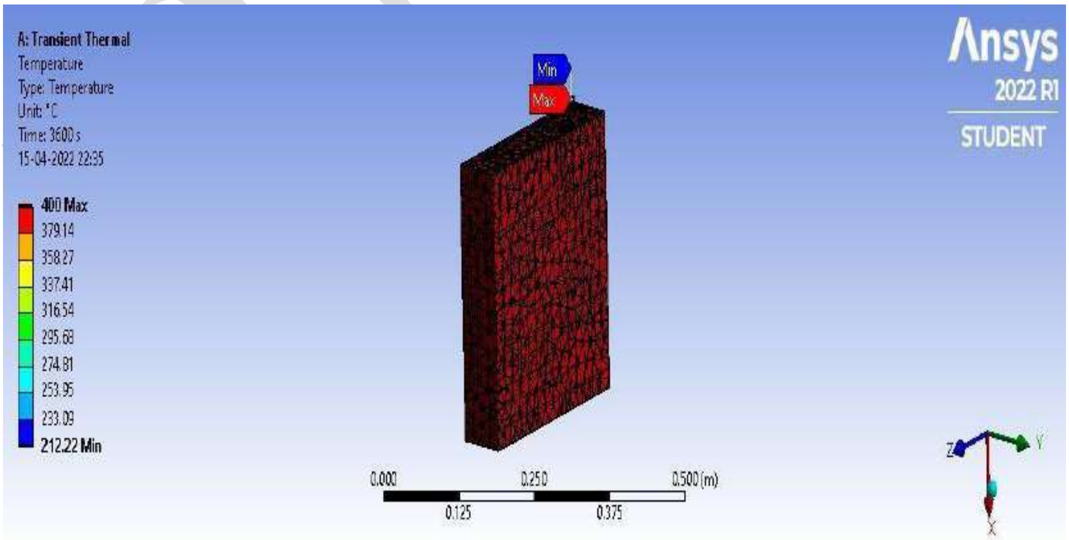

Fig. 4 Temperature Distribution of Top Surface of delta glaze coated specimen.

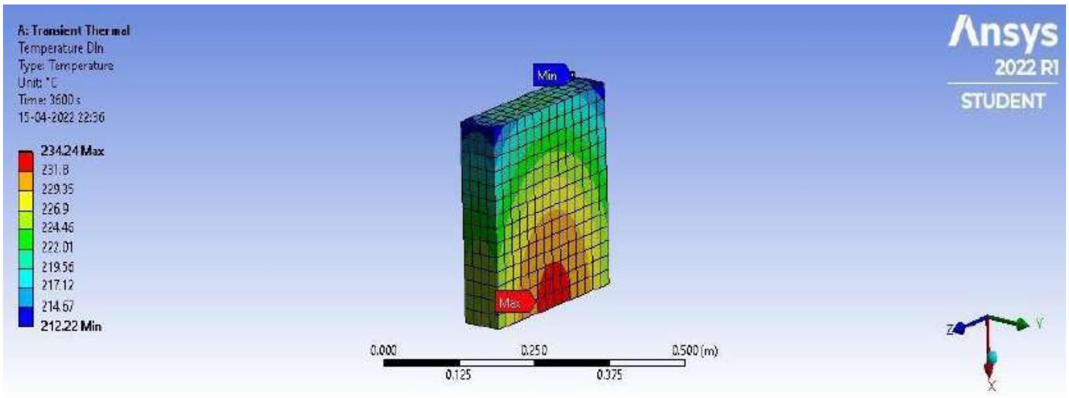

Fig. 5: Temperature distribution on the die surface below the delta glaze coated surface.

For validating the result and finding heat transfer coefficient, two specimens with the same material of Die (Din 2714) 290x290x70mm have been taken in which one is coated with Delta glaze and the other is kept uncoated. They are heated up to a temperature of 550°C in an electric furnace and allowed to cool in air.

Fig. 6: Specimen 290x290x70 coated with delta glaze coating

CALCULATION OF HEAT TRANSFER COEFFICIENT

Temperature distribution in transient conduction is given by the relation

$$\frac{t - t_a}{t_i - t_a} = e^{-\frac{hA_s\tau}{\rho VC}}$$

Substituting the values of temperature in the above equation, the value of heat transfer coefficient was determined. The value of heat transfer coefficient in each node included finite element analysis and the temperature distribution on each node is approximately same as the actual process has been done

ANALYSIS OF MODELS OF DIE USING ANSYS

The analysis was conducted with delta glaze coated die and uncoated die. The analysis of upper half of die without coating is shown in figure given below.

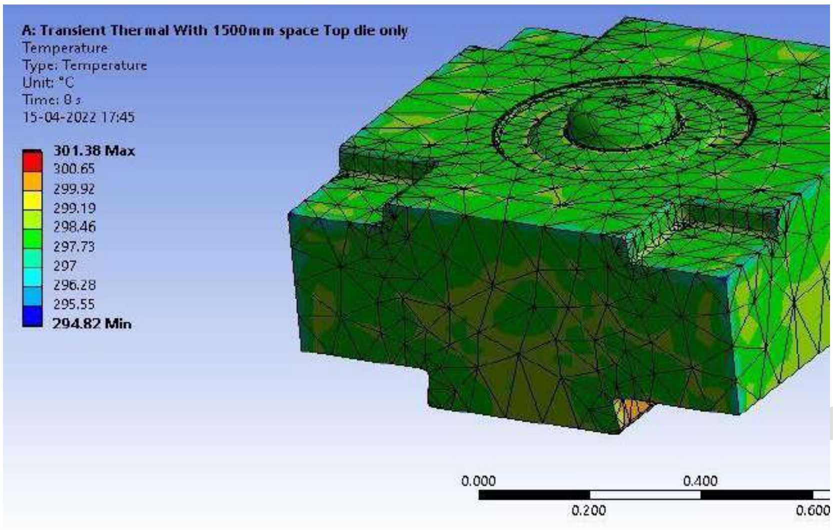

Fig. 7: Analysis of Top half of Die without Coating

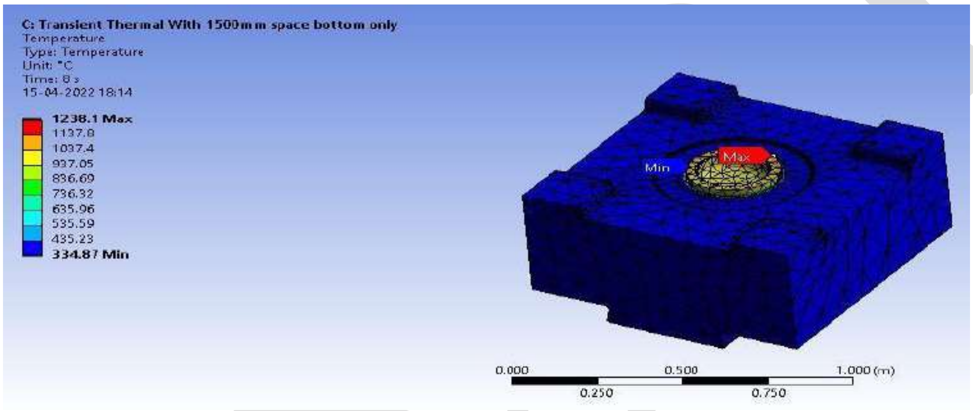

Fig. 8 Analysis of Bottom half of Die and product without coating

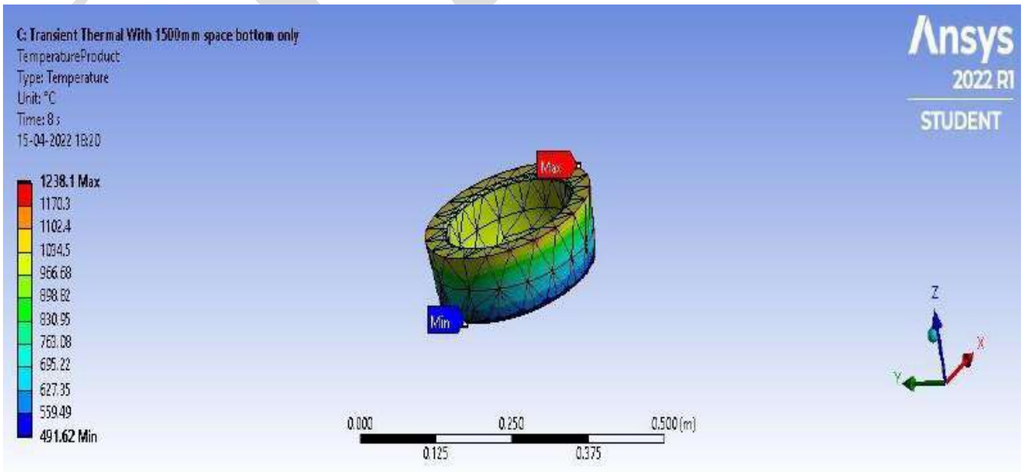

Fig. 9: Analysis of Product

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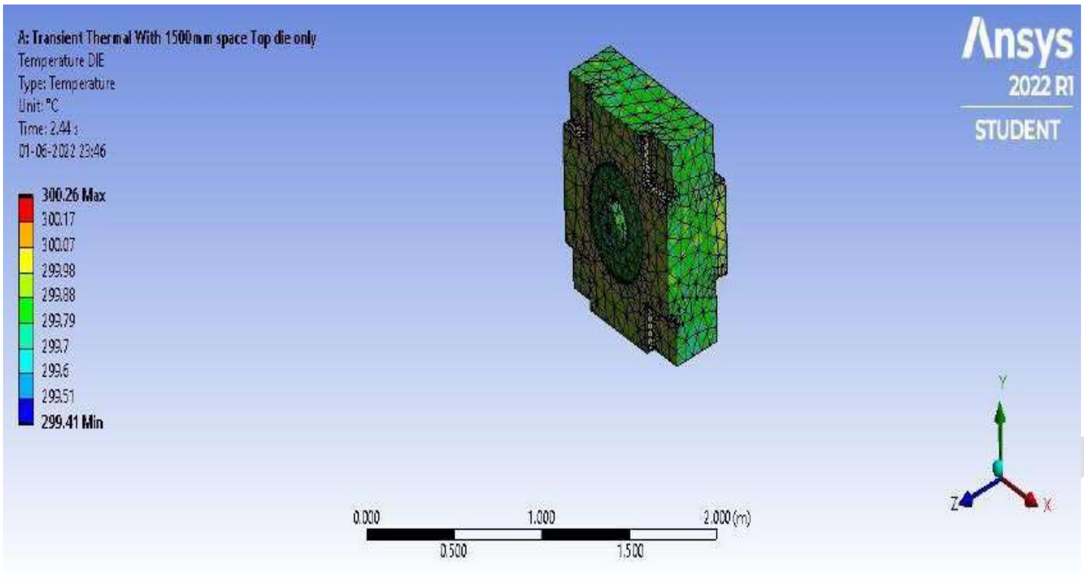

Fig. 10: Analysis of Top

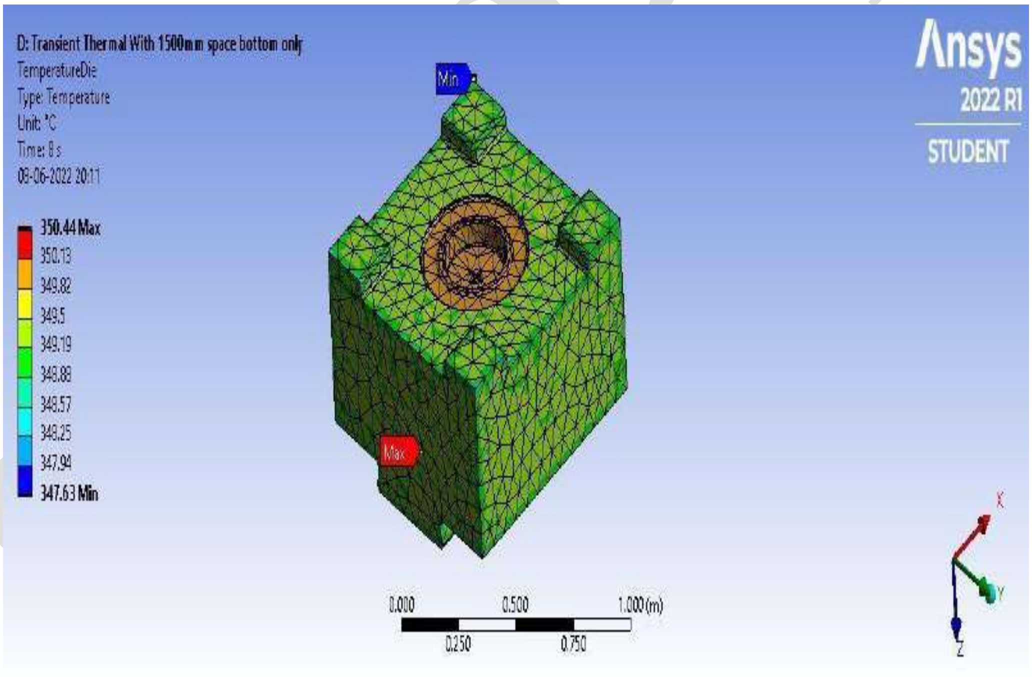

Fig. 11: Analysis of Bottom die with coating

EXPERIMENTAL ANALYSIS

Die was coated with delta glaze FB412 to a thickness of 1 mm on the Die Surface using brush. 20 minutes drying time was given between each coat. Die was placed in a Die heating furnace and heated up to 350°C for 6 hrs. Die top and bottom halves were fitted in forging hammer. Preheated billet of waspaloy at the temperature 1020°C was placed inside the Die cavity.

RESULTS AND DISCUSSIONS

Analysis using Ansys reveals a significant temperature drop with each blow, and before the work is complete, the product's temperature falls below the forgeable range. Comparing Ansys results, the temperature drop for the coated die is significantly lower than that for the uncoated die. For the coated die, the average temperature drop per blow is only 0.35°C for the bottom half and 0.85°C for the top half. Thus, applying a glass coating on the die surface reduces heat loss from the die and product surface, keeping the billet within the forging temperature range. This analysis demonstrates that surface coating is an effective method for conventional hot forging of Waspaloy.

Temperature vs. time graphs for the upper and lower halves of the die are shown below.

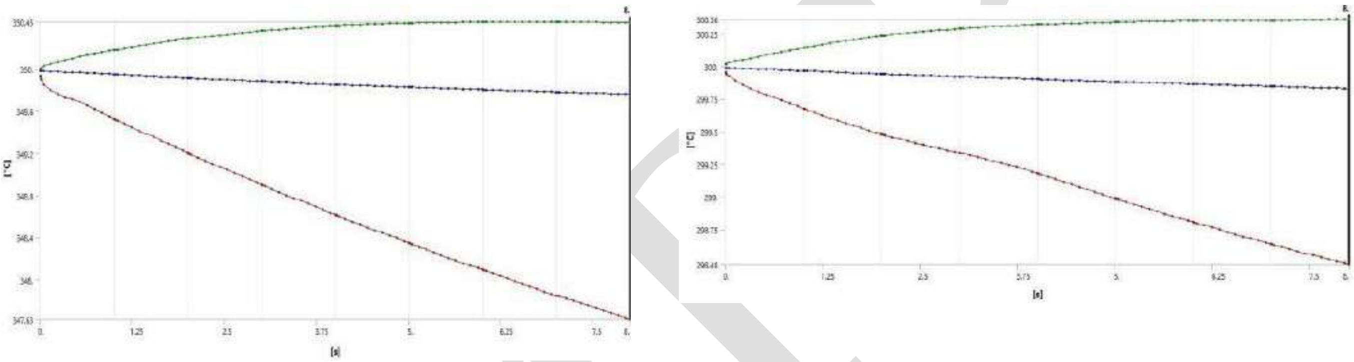

Fig. 12: temperature vs time of delta glaze coated die (top & bottom)

[Green line - maximum temperature line, blue line - average temperature line, red line - minimum temperature line] Plastic deformation was observed in the upper half of the die due to a larger temperature drop compared to the lower half. The lower half, being in contact with the hot billet, experiences minimal temperature drops. Ansys analysis confirmed that the upper half of the die undergoes greater temperature drops. Die failure is caused by heat loss from both the die and billet surfaces and the narrow forgeable temperature range of Waspaloy. Despite these challenges, the actual forging process of Waspaloy using a conventional hot forging setup with a Delta Glaze coated die was successfully completed. There were no cracks on the product, which maintained close dimensional tolerances. Additionally, no plastic deformation was found on the die surface after the process was completed. Finally, the product was forged without any cracks or deformations. Also, the dies also suffered no damages.

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